Descriptions of Past Research

EPRI Fossil and Nuclear Steam Turbines-Generators and Auxiliary Systems – 2017

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EPRI Program Manager
S. Hesler

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

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Principal Investigator
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PRODUCT DESCRIPTION

This document contains summaries of many past Electric Power Research Institute (EPRI) Turbine-Generator Research Program research and development (R&D) efforts.

Objectives

This document will assist plant personnel responsible for turbine-generator maintenance, operation, risk management, and troubleshooting in quickly locating the appropriate EPRI research reports found on EPRI.com.

Approach

A compilation of over one hundred and fifty product summaries describing EPRI research performed over the previous fifteen years is contained in this document. The summaries are arranged into nineteen categories covering outage management, procurement, failure mechanisms, monitoring, inspection, and staff education. Each product summary contains a description of the objective, approach, and results, in addition to an EPRI perspective.

Results

This research report catalog contains abstracts from the most recently released reports that address current turbine-generator reliability issues. Many more documents can be found on the Program 65 Cockpit page of EPRI.com.

Applications, Value, and Use

This document is a useful reference resource for EPRI member organizations who are seeking past reports on specific topics of interest. EPRI will update this document yearly to include new research reports and software produced by the Turbine-Generator Program.

EPRI Perspective

The EPRI Turbine-Generator Research Program produces over ten reports annually. These are valuable resources when used by member staff, and this document will facilitate timely access to these reports. EPRI member companies are encouraged to have this resource readily available and distribute to all key staff in their organization for use as a primary reference document when turbine-generator availability issues arise.

Keywords

Exciters
Generator
Past products
Past research
Steam turbines
Turbogenerators

CONTENTS

1
TURBINE GENERATOR OUTAGE PLANNING AND EXECUTION

Guideline for Developing Turbine-Generator End-of-Life Maintenance Strategies - 3002006241

Product Type: Technical Report Date Published: 21-Dec-2015

Abstract

This report describes turbine-generator maintenance practices that require modification or may be eliminated given a fixed horizon for plant retirement. By evaluating practices that will keep reliability within targets, plants can run to retirement cost-effectively without spending additional resources on an asset that is not viable in the long term.

Background

Power production is a capital-intensive and highly regulated industry requiring proper asset management of the utility fleet for long-term success. As economic and regulatory conditions continue to evolve, power plants that were once economically viable may be decommissioned. These plants may be older, less efficient, or have difficulty meeting new regulatory requirements. For these and many other reasons, it may be appropriate to retire these plants and focus on other assets to provide safe, reliable, and economic power to the public.

Once the decision to retire a plant is reached and a date set, the maintenance philosophy changes from one of indefinite operation to one of end-of-life management. This situation requires a different approach to preventive maintenance (PM) practices, plant staffing, and capital expenditures to ensure the safe and reliable operation of the retiring asset while preserving resources that may be better spent improving the condition of the remainder of the fleet.

Even in an environment of a known shutdown date, major components and balance-of-plant equipment require regular inspections and maintenance to ensure personnel safety as well as continued operation until shutdown. However, many plant maintenance practices are designed to extend component life for periods that may exceed the remaining plant life. Other practices may not meet the challenges of equipment operational changes as a result of imminent plant retirement. In these cases, senior plant management may see value in reevaluating established maintenance practices.

Objective

This report is intended to provide plant staff with guidance for developing appropriate end-of-life maintenance strategies and techniques for turbines, generators, and auxiliary systems that ensure acceptable availability while conserving resources.

Approach

This guideline was developed using the EPRI Preventive Maintenance Basis Database (PMBD) as a significant source of information related to preventive maintenance of turbine-generators and the immediate auxiliary support systems. The information gained from the PMBD includes failure mechanisms affecting the equipment or component, the purpose of the PM, tasks to be performed, and PM interval. This information was supplemented by the technical expertise of engineers experienced with power plant turbine-generator systems.

Results

This report provides guidance to the utility with a known plant shutdown schedule for the development of appropriate end-of-life maintenance strategies and techniques for turbines, generators, and immediate auxiliary support systems. Such maintenance strategies facilitate availability while conserving resources by weighing susceptibility and consequence to develop an acceptable risk profile.

Applications, Value, and Use

Although this report is focused on fossil-powered plants, it is equally applicable to a nuclear power plant.

Several factors, including economic and regulatory-driven factors, may cause a plant owner to permanently remove a power generating plant from service. The decision to remove a plant from service will likely cause changes in the operating scenario for the plant and bring into question the need to continue the same level of resource allocation for PM of the turbine-generator and its immediate auxiliary support systems during the end-of-life period. EPRI's PMBD contains a significant amount of information that can be used to evaluate established PM tasks to determine the degree to which their continued performance is required. However, the PMBD is heavily focused on nuclear plants, and there are many PM activities that are not addressed in the PMBD.

This report provides plant management with a methodology for evaluating established PM tasks using predetermined criteria to determine which must be continued without modification, can or should be modified, or can be omitted over the end-of-life period. Although this guideline presents an approach for evaluating individual PM tasks in isolation, it also addresses other concerns that must be integrated into the evaluation process—including the accumulative risk of modifying and/or omitting multiple PM tasks, periodic reevaluation based on PM feedback, and the potential introduction of a need for new PM activities based on a change in operating scenario.

It must be recognized that a utility's end-of-life strategy is a living document. The PM evaluation methodology described in this report should be approached as an iterative process requiring repeated evaluations based on feedback from PM performance, particularly for critical PM activities.

Keywords

Decommissioning
End-of-life
Maintenance strategy
Preventive maintenance
Turbine-generator

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006241

Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections - 2016: Supplemental Addition - 3002008431

Product Type: Technical Report Date Published: 20-Dec-2016

Abstract

Up to 70% of the outages planned for conventional steam power plants involve work on the turbine. The challenge for the engineer is to improve performance and extend reliability while eliminating unproductive activities from the maintenance outage schedule. This report provides general guidelines for planning and performing maintenance on steam turbines during outages.

Background

As a focus of innovative approaches and techniques, maintenance of aging steam turbines has assumed increased importance. In 2013, coal-fired steam plants were an average of 42 years old, and oil- or gas-fueled plants were an average of 46 years old. Many old steam plants, particularly those that are coal fired and well maintained, can be positioned to succeed in the current deregulated environment. To support this goal, EPRI is developing a series of engineering guidelines, repair procedures, and support technologies, which is compiled on a DVD titled *Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections–2016* (EPRI product 3002008430 for 2016).

Objective

To provide general guidelines for planning and performing a steam turbine maintenance outage

Approach

Material that was added to the individual Guidelines volumes for 2016 was assembled into this technical update by volume number. For 2016, this consisted of additions or changes to Volumes 1 and 4, as detailed below.

Results

This technical update contains only the material that has been added to the 2015 edition of the Guidelines:

Volume 1:

- Section 2.1.1.2
- Section 2.11
- Appendix D
- Appendix E

Volume 4:

- Section 15
- Section 18
- Section 19
- Appendix N
- Appendix Q

EPRI Perspective

This technical update represents the technical information added to the Guidelines project for 2016.

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Maintenance
EHC fluid
Steam turbines
Accelerated cooling
Casing distortion
Steam/water purity

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008431
Your company's price: No ChargeThis Product is available to you at no additional charge as part of your membership.

Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections-2016 - 3002008430

Product Type: Technical Report Date Published: 14-Dec-2016

Abstract

EPRI has produced an extensive volume of information that supports best practices for turbine repair and maintenance. This software presents this information in an organized and searchable format to improve ease of use for users.

Benefits and Value

Guidelines for Reducing the Time & Cost of Turbine-Generator Maintenance Overhauls and Inspections will allow for the following:

- Browser: Internet Explorer 11+
- Operating System: Windows 7 (32-bit and 64-bit), Windows 8.1, and Windows 10
- Screen Resolution: 1024 X 768
- RAM: Minimum required for Operating System
- Processor: Minimum required for Operating System
- Hard Drive Space: 70MB of storage
- Animations: Adobe Flash Player 11.0+ is needed to view some of the media in the course. If it is not included with your browser, you can download it from http://www.adobe.com/downloads/ .
- Video: Windows Media Player is needed to view the video in this course. If it is not installed on your computer, you can download it from https://support.microsoft.com/en-us/help/14209/get-windows-media-player. The Firefox browser plugin is available from http://www.interoperabilitybridges.com/Windows-Media-Player-Firefox-Plugin-Download. If you are not able to download a plugin using the provided links, you may perform a web search for the Windows Media Player plugin appropriate to your browser.
- Note that newer versions of Firefox default to disabling plugins after update. To enable plugins after an update, follow these steps:
    1. At the top of the Firefox window, click on the Tools menu, and then click Add-ons. The Add-ons Manager tab will open.
    2. In the Add-ons Manager tab, select the Plugins panel.
    3. In the list of plugins, select the Windows Media Player plugin. To re-enable the plugin, select Always Activate in its drop-down menu.

- Pop-up Blocking: This course uses pop-up windows to provide additional content and navigation options. Please disable any pop-up blocking software.
- Blocked Content: You will need to allow blocked content to use the interactive features of this course. If you receive this message at the top of your browser window, click it and click Allow Blocked Content: "To help protect your security, Internet Explorer has restricted this webpage from running scripts or ActiveX controls that could access your computer. Click here for options..."

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Guidelines
Computer based training
Turbine generator
Turbine Repair
Turbine Maintenance

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008430

EPRI Preventive Maintenance Basis Database (PMBD) Version 3.1 - 3002005428

Product Type: Software Date Published: 30-Jun-15

Abstract

The PMBD (Preventive Maintenance Basis Database) is an information system that contains the maintenance schedules for the major components and valves in power generating facilities. This information is essential in allowing power generating facilities to plan and monitor very close the maintenance schedules, along with controlling and managing the costs associated with generating power.

To access this application please click https://pmbd.epri.com/Landing.aspx

Benefits and Value

- Functional Equipment Groups have been added to allow users to perform a task-by-task analysis of a collection of components.
- The vulnerability algorithm has been updated to add 3 different types of calculations for users.
- The vulnerability algorithm has been updated to allow users to reduce task effectiveness while running vulnerability.

System Requirements

- The default web server will be Windows 2008 R2 Server.
- The default back-end database will be Microsoft SQL Server 2008 R2.

The following browsers will be supported:

- Firefox 10.x and higher
- Chrome – Most current version

Keywords

PMBD
Preventive Maintenance Basis Database (PMBD) Task Intervals
Vulnerability

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005428

Steam Turbine Bolting Maintenance Guide: Revision 1 of 1013341 - 1016958

Product Type: Technical Report Date Published: 25-Jun-08

Abstract

This report provides nuclear and fossil plant personnel with current maintenance information on assembly and disassembly techniques, failure modes, inspections, and replacement materials for steam turbine bolting.

Background

Input from members of the Turbine-Generator Program indicated increased concerns for high-temperature bolting used on steam turbines. With the age of the steam turbines, replacement of bolting in high-temperature applications has occurred and will continue to occur as the number of thermal cycles accumulates. It is important to know the condition of the existing bolting and to anticipate replacement of bolting that does not meet the criteria for continued service.

Objectives

- To provide technical information for the inspection, testing, and replacement of steam turbine bolting
- To provide plant maintenance personnel with the current methods of assembly and disassembly of bolted turbine joints

Approach

A Technical Advisory Group was formed that consisted of steam turbine owners from members of the EPRI Steam Turbines, Generators, and Balance-of-Plant Program and the Nuclear Steam Turbine Initiative Program. Extensive research was performed on the bolting materials used in the industry.

Results

The guide includes a technical description of bolting design and nomenclature. The tooling, assembly/disassembly procedures, material selection, and inspection criteria are the main topics of the guide. Failure modes, bolting specifications, and industry contacts are also included.

EPRI Perspective

There are as many as 800 bolts and studs used in a modern steam turbine design. The function of the bolting is to maintain a tight joint with no steam leakage into the plant. Steam leaking from high-pressure joints may require maintenance outages and costly repairs. The inspection, testing, and replacement of turbine bolting ensure the integrity of the bolting and continued safe operation of the steam turbine unit.

Keywords

Bolting materials
Nondestructive examination
Turbine bolting
Inspection
Reliability

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001016958

2
TURBINE GENERATOR COMPONENT PROCUREMENT AND OUTAGE MANAGEMENT

Large Steam Turbine Component Retrofits and Replacements: Lessons Learned - 1019648

Product Type: Technical Report Date Published: 19-Dec-10

Abstract

This guide provides information that will be of interest to utilities considering retrofit and replacement projects for life extension and performance improvement of fossil and nuclear steam turbine-generators. The report provides a summary of the risks that a utility should consider when retrofitting or replacing turbine-generator equipment and presents methods for mitigating those risks. Potential pitfalls, best practices, and lessons learned by the industry provide additional insights.

Objectives

As steam turbine-generators age and the landscape of existing suppliers changes shape due to mergers, acquisitions, and business failures, it may become more difficult to find OEMs to provide direct retrofit equipment. The information provided in this report will help plant managers and utility design and engineering departments to improve the success of steam turbine-generator retrofit and replacement projects, whatever their choice of vendor.

Approach

This report was developed by surveying existing EPRI publications and other available documents and obtaining input from various utility sources. Other input came from a turbine-generator workshop held to identify potential pitfalls and lessons learned. In addition, a survey was conducted to determine the amount of steam turbine-generator retrofit and replacement work that is anticipated by EPRI members and collect details regarding past experience with such projects. The information was then organized and reviewed by a technical advisory group (TAG) to ensure that the report adequately addressed the issues.

Results

There is a varied range of experience in the generation industry in terms of how utilities meet their needs for retrofitting and replacement of steam turbine-generator equipment. Some utilities have always used original equipment manufacturer (OEM) equipment and rely almost exclusively on the OEM to provide replacement equipment and parts, while others always consider available third-party (non-OEM) equipment. Today's competitive market has led to some attractive claims of improved performance, superior quality, and favorable pricing.

The utilities that routinely use non-OEM equipment have established procurement policies and engineering support to evaluate bidders, assess technical issues, and manage risks. They always include OEMs in the bid process and specify their requirements. All bidders bid to the same specification, and the company can determine which offering provides the best value. Other utilities, with limited engineering resources, tend to specify more general requirements and rely more heavily on the bidders (both OEM and non-OEM) to provide detailed equipment specifications and other criteria. This requires additional effort to evaluate the bids and select the best value for the equipment.

Application, Value, and Use

As the traditional OEMs serving turbine-generator owners continue to change and more non-OEM providers emerge, the marketplace will offer new technologies, improved performance, and increased equipment life spans. Utilities will need to assess the value of these offerings, balanced with the probability for success. This report outlines some of the critical areas of concern that must be addressed for a turbine-generator refit or replacement project to be successful under today's conditions.

EPRI Perspective

Because up to 70% of outages planned for steam power plants involve work on the turbine, power producers continually seek ways to optimize operation and maintenance (O&M) activities on aging turbine-generator fleets. Optimized O&M can reduce maintenance costs, improve component reliability, and increase generator output. Maintaining a detailed awareness of effective maintenance techniques, however, is challenged by the evolutionary nature of operating experience, by the complexities of advanced materials and upgrade options, and by reduced staffing levels and retirement of experienced personnel. This report is designed to help utility engineers, project managers, procurement specialists, and senior management understand the issues involved in turbine-generator retrofit and replacement projects and benefit from the lessons learned by others.

Keywords

Non-OEM
OEM Replacement
Retrofit
Steam turbine-generator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001019648

Shipping Preparations and Storage of Turbine and Generator Components - 1022193

Product Type: Technical Report Date Published: 01-Nov-10

Abstract

Many utilities are replacing major components in their units and are becoming increasingly concerned with shipping as well as long- and short-term storage of these replacement components, which arrive on site for immediate use or as backup in case of emergency. The choice of storage location depends on space availability, site security, environment, tracking and accessibility of stored equipment, original equipment manufacturer (OEM) requirements, and component inspection or maintenance requirements during storage. This report provides a comprehensive source of information that will enable utilities to identify possible safety hazards, evaluate risks, and select the shipping and storage processes most conducive to increased safety, reliability, and availability.

Objectives

The goal of this project was to publish a comprehensive guide that combines OEM and worldwide utility best practices and procedures for shipping and storage of major turbine and generator components. This goal fits into the broader objectives of EPRI's Steam Turbines-Generators and Auxiliary Systems Program (Program 65), to undertake research and technical support activities that will enable power plant operators to reduce operation and maintenance costs, maximize plant performance, and more effectively implement plant upgrades and asset management strategies.

Approach

This report is organized according to:

- Shipping preparations for each component
- Storage practices for each component
- Inspection and maintenance requirements for each component
- Safety considerations

Results

This guideline has been designed to help utilities identify and document industry best practices for shipping and storage of spare major turbine and generator components. Components addressed include turbine and generator rotors, stators, turbine stationary components (diaphragms/blade rings), generator retaining rings, stator coils/bars, steam turbine inner and outer shells, generator stators, crossover piping, turning gear, main oil tanks, lubrication system piping, and high-voltage bushings. Following are some important considerations:

- Shipping preparations for major turbine and generator components to a destination should take into consideration the means, methods, packaging, weather conditions, and monitoring of the component during transportation.

- A planned inspection and maintenance program should be developed for each steam turbine and generator component in storage. Planned component inspections should be based at a minimum on the OEM recommendations and adapted to site-specific conditions. A checklist for each component should be developed with specific inspection items and instructions.
- Procedures should be developed that outline site-specific safety requirements for handling, application, and removal of preservatives and coatings that protect equipment during shipping and storage.

Application, Value, and Use

The main objectives of preparing a component for shipment or storage should be to 1) provide protective means to eliminate or greatly decrease chances of physical damage, 2) reduce or eliminate exposure to moisture and corrosive environments, and 3) address any other adverse conditions that could be encountered during shipping or storage. The OEM of the steam turbine/generator component in question should be contacted for specific shipping and storage instructions and advice if special circumstances are warranted or exist.

EPRI Perspective

Many power producers upgrade steam turbines and generators in order to gain megawatts instead of installing new capacity. This guide provides a single point of reference for plant engineering and maintenance personnel as they face the wide variety of engineering challenges associated with procurement, shipping, and storage of steam turbine and generator replacement components. Through use of this guide, EPRI members should be able to significantly improve the processes associated with upgrading and repairing steam turbines and generators in order to increase plant output.

Keywords

Component Shipping
Component Storage
Generator
Components System
Inspection System
Maintenance System
Upgrades Turbine
Components

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001022193

3
TURBINE GENERATOR AUXILIARY SYSTEMS MAINTENANCE GUIDES

Turbine Generator Auxiliary System Maintenance Guide Volume 4: Generator Stator Cooling Water System: 2013 Update - 3002000420

Product Type: Technical Report Date Published: 19-Dec-13

Abstract

Large generators have been designed to use a variety of cooling methods. Originally, and still to some extent today, stator windings have been cooled with air. As generators became larger, hydrogen cooling was introduced, and in 1956 water cooling of stator bars and rotor bars became popular. While water cooling is a mature technology, this report examines the specific features of water cooled generators and the attached generator cooling water system, with emphasis on water cooled stators.

Background

Experience has identified typical problem areas, the most important among them being 1) leaks of hydrogen into the stator cooling water, 2) leaks of stator cooling water out of the winding, 3) plugging of the coolant path in the winding, and 4) clogging of the coolant path outside the winding.

Objectives

- To summarize the specific features of the generator stator cooling water system as well as related operation, monitoring, and maintenance issues.

Approach

Drawing on published information, original equipment manufacturer (OEM) documentation, and personal experience, the project team has structured and summarized the major technical problems and solutions associated with the generator stator cooling water system. An advisory panel of experts and industry specialists have provided critical assessment and further technical information that a small group of authors could never have accessed. The authors' group was comprised of engineers of differing technical backgrounds, with the goal of bringing in complementing views and experiences.

Results

In addition to describing the various types of water cooled generators, their cooling systems, and components, this report provides related specifications for operation and layup along with recommendations for monitoring and maintenance. An appendix discusses frequent trouble spots and hands-on experience reports with troubleshooting. The report recommends that operators:

- Implement design conditions, allow the system find its equilibrium, then maintain the system in that condition
- Not convert stator water chemistry to another chemistry regime
- Be aware of water chemistry status, trend parameters, and investigate any changes
- Ensure communication between the generator engineer and the plant chemist
- Be proactive in preventing or mitigating flow restrictions
- Be proactive in cleaning in the event of flow restrictions
- Investigate and mitigate the root cause of flow restrictions, since cleaning the stator bars alone will provide temporary relief but may not solve the problem
- Ensure that dissolved oxygen content of makeup water corresponds to the dissolved oxygen of water already in the system
- Keep internal gas-to-water leakage small and, in case of significant leaks maintain hydrogen purity higher than 98%
- Control stator winding layup
- Research and understand the root cause of out-of-normal conditions

Application, Value, and Use

This unbiased and comprehensive report should give the generator engineer an understanding of the system chemistry and the plant chemist an understanding of the major electromechanical features of the turbo generator stator cooling water system. This document is intended to encourage both the generator engineer and the chemical engineer to work jointly in meeting technical challenges resulting from system particularities and vulnerabilities.

Keywords

Flow restrictions
Generator monitoring and maintenance
Out-of-normal conditions
Turbo generator stator cooling water system
Water cooled generators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000420

Turbine-Generator Auxiliary Systems, Volume 1: Turbine Generator Lubrication System Maintenance Guide – 2012 Update - 1025331

Product Type: Technical Report Date Published: 12-Dec-12

Abstract

This report provides nuclear and fossil plant personnel with current maintenance information on lubrication system components and specifications, treatment, and analysis of the lubricating oil.

Background

Input from member utilities indicated that maintenance guides were needed for the turbine-generator auxiliary systems. The first auxiliary system selected was the turbine-generator lubrication system used in nuclear and fossil power plants.

Objectives

- To assist plant maintenance personnel in the identification and resolution of problems with components in the turbine-generator lubrication system
- To provide lubricating oil specifications, operating parameters, laboratory testing recommendations, troubleshooting, and analysis
- To provide a comprehensive maintenance guide for the turbine-generator lubrication system

Approach

A Technical Advisory Group was formed that consisted of turbine-generator equipment owners from members of the EPRI Steam Turbines, Generators, and Balance-of-Plant Program. The guide was developed as two independent parts. The first part covers the maintenance of the lubrication system components. The second part covers the parameters of the lubrication fluid.

Results

The guide includes a description of the lubrication system components for the major manufacturer-supplied systems. Technical description, troubleshooting, and preventive and component maintenance are the main topics in the equipment maintenance section. A preventive maintenance basis (PM Basis) was developed for the guide. Technical description and sampling and analysis recommendations are the main topics in the lubricating oil section. Safety issues are included for the component and oil sections of the guide.

EPRI Perspective

The purpose of the turbine-generator lubrication system is to provide oil at an acceptable temperature, pressure, quantity, and cleanliness to the bearings and control system devices. The reliability of this system is critical to the performance of the turbine-generator equipment. The consequences of not providing oil at the prescribed parameters can result in conditions including high bearing vibration, damaged bearings, thrust bearing failures, associated forced outages, lengthy repair outages, and sluggish responding controls.

Keywords

Lubricating oil
Lubrication system
Oil testing and analysis
Preventive maintenance (PM)
Preventive maintenance basis (PM Basis)
Reliability

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001025331

Turbine-Generator Auxiliary Systems, Volume 2: Turbine Steam Seal System Maintenance Guide - 1013462

Product Type: Technical Report Date Published: 14-Dec-06

Abstract

The Turbine-Generator Auxiliary Systems, Volume 2: Turbine Steam Seal System Maintenance Guide provides nuclear and fossil plant personnel with operation and maintenance guidance on the turbine steam seal system components.

Background

Input from member utilities indicates that maintenance guides are needed for the turbine-generator auxiliary systems. The first auxiliary system selected was the turbine-generator lubrication system for nuclear and fossil power plants. Turbine-Generator Auxiliary Systems, Volume 1: Turbine-Generator Lubrication System Maintenance Guide (EPRI report 1010191) was published in December 2005. The second auxiliary system selected was the turbine steam seal system used in nuclear and fossil power plants.

Objectives

- To assist plant maintenance personnel in the identification and resolution of problems with equipment in the steam seal system
- To provide a comprehensive maintenance guide for the steam seal system equipment

Approach

A technical advisory group was formed that consisted of turbine-generator equipment owners from members of the EPRI Nuclear Steam Turbine Initiative and the Steam Turbines, Generators, and Balance-of-Plant Program. Input on current maintenance issues related to the steam seal system was solicited, and key suppliers of steam seal components were solicited for input and to review the report. In addition, a search of EPRI literature was conducted to include the latest technologies available.

Results

This report includes a description of a typical turbine steam seal system, including various pieces of equipment and their functions. Preventive/predictive maintenance and condition monitoring are the main topics of the equipment maintenance section. A preventive maintenance basis was also developed for this report.

EPRI Perspective

The turbine steam seal system prevents steam from leaking into the atmosphere from the high-pressure and intermediate-pressure turbine and prevents air from leaking into the low-pressure turbine. This system must be in operation for a vacuum to be established in the condenser and thus, for the turbine-generator to operate. The steam seal system requires little maintenance and has not proven to be a cause of significant problems over the years. Regular preventive/predictive maintenance functions and condition monitoring are required to ensure the reliability and dependability of the steam seal system.

Keywords

Condition Monitoring
Gland Seal
Maintenance
Preventive Maintenance
Reliability
Steam Seal

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013462

Turbine-Generator Auxiliary Systems, Volume 3: Generator Hydrogen System Maintenance Guide - 1025330

Product Type: Technical Report Date Published: 03-Dec-12

Abstract

The updated Turbine-Generator Auxiliary Systems, Volume 3: Generator Hydrogen System Maintenance Guide provides nuclear and fossil plant personnel with operation and maintenance guidance on the generator hydrogen system.

Background

Input from member utilities of EPRI Program 65 as well as the Institute of Nuclear Power Operations (INPO) have indicated that maintenance guides are needed for turbine-generator auxiliary systems. The first auxiliary system selected for this maintenance guide series was the turbine-generator lubrication system used in nuclear and fossil power plants, documented in Volume 1 (1010191, December 2005). The second auxiliary system selected was the turbine steam seal system used in nuclear and fossil power plants, documented in Volume 2 of this series (1013462, December 2006). The third auxiliary system selected was the generator hydrogen system, documented in Volume 3 of this series (1015066, December 2007).

Objectives

- To provide a comprehensive guide for the generator hydrogen system, by updating and expanding EPRI product 1015066.
- To assist plant operation and maintenance personnel identify and resolve problems with the generator hydrogen system.
- This update supersedes 1015066 report.

Approach

A technical advisory group was formed that consisted of turbine-generator equipment owners from EPRI member utilities. Input was solicited for the content of the guide and review of the draft materials. In addition, input and review was solicited from the major generator manufacturers. The industry sources at INPO and industry bulletin board/databases, including GETURBGEN (General Electric Turbine-Generator), TEN (Turbine Engineer Network), and IGTC (International Generator Technical Community), were researched for applications to the generator cooling system.

Results

This report includes information on the following subjects:

- Hydrogen safety
- Why hydrogen is used as a cooling medium in generators
- Basic generator design
- Hydrogen cooling systems
- Purging and filling a generator
- Hydrogen system instrumentation

- Monitoring and potential problems
- Locating and qualifying hydrogen leaks
- Repairing leaks on-line
- Precautions during crawl-through inspections
- Hydrogen system maintenance

The appendices include information on hydrogen, including a material safety data sheet (MSDS), potential ignition sources of hydrogen, one vendor's training summary for safe handling of hydrogen, and advanced generator purging technologies for improved safety and reduced outage time.

EPRI Perspective

The safe and reliable operation of the generator is crucial to the fossil and nuclear plant's ability to produce power. While hydrogen is the most effective cooling medium for the generator, there are precautions that must be taken to ensure that hydrogen supplied to the generator is pure, at the correct pressure, and contained within the generator casing. The mixing of hydrogen with air in the presence of a spark can produce an explosion. This updated guide will prove particularly valuable to utilities in its documentation of industry best practices for generator hydrogen system maintenance.

Keywords

Generator
Hydrogen
Inspection
Leaks
Maintenance
Safety

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001025330

Turbine-Generator Auxiliary Systems, Volume 5: Main and Feedpump Turbine Trip Systems - 1017486

Product Type: Technical Report Date Published: 23-Dec-09

Abstract

This report describes the trip systems for the mechanical hydraulic control (MHC) and electrohydraulic control (EHC) main turbine and feedpump turbines for the General Electric (GE) and Siemens Westinghouse (SW) units in the United States.

Background

The turbine trip system consists of the trip devices that protect the main turbine from damage in operation caused by speed, pressure, mechanical damage, and conditions external to the turbine. The main turbine trip systems for the GE Mark I, II, IV, and V and the SW EHC systems are included in this report. The feedpump turbine trip systems for the GE UT70 and the mechanical drive turbine 20 and SW feedpump turbine control systems are covered in this report. The trip systems for the GE MHC systems and the SW digital EHC and analog EHC systems are covered in Electric Power Research Institute report 1019313, Steam Turbine Mechanical Hydraulic Control System—Operation, Inspection, Setup, Troubleshooting, and Maintenance Guide, Revision 1.

Objectives

- To provide power plant technical personnel with a comprehensive report for operating, maintaining, inspecting, testing, and troubleshooting the main and feedpump turbine trip systems

Approach

This report includes technical descriptions and information about operation, inspection/testing, maintenance practices, and troubleshooting on the main turbine and feedpump turbine trip systems in fossil and nuclear power plants.

Results

This report includes descriptions of each of the turbine control systems and their components, a description of the operation of the trip devices, instructions on testing and inspecting the devices, information on maintenance practices, troubleshooting guidelines, a glossary of terms, and references for each turbine trip system.

EPRI Perspective

This report provides power plant technical personnel with comprehensive information on operating and maintaining the turbine trip mechanisms to ensure adequate protection of the turbine equipment.

Keywords

Electrohydraulic controls (EHCs)
General Electric (GE)
Mechanical hydraulic controls (MHCs)
Siemens Westinghouse (SW)
Trip system

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001017486

Turbine-Generator Auxiliary Systems, Volume 6: Turning Gear Maintenance Guide - 1019645

Product Type: Technical Report Date Published: 23-Dec-10

Abstract

The Electric Power Research Institute's (EPRI's) Steam Turbine-Generators and Auxiliary Systems program (Program 65) produces a series of steam turbine and generator auxiliary system maintenance guides covering best practices for preventive, predictive, and routine maintenance and troubleshooting. This volume is devoted to the maintenance of steam turbine turning gear systems and is Volume 6 in the series. The volume addresses turning gear assemblies of the major original equipment manufacturers (OEMs), as found in fossil and nuclear power plants.

Background

Large steam turbines are equipped with a turning gear assembly to slowly rotate the turbine and generator rotors during periods of cooling down after a shutdown, while warming during startup, and during periods when the unit is off-line and on standby. In this document the reader should be made aware that the major turbine-generator component affected by thermal stresses is the steam turbine. The components, especially rotors, can be damaged as a result of thermal stresses when uneven cooling or heating is allowed to take place. Rotation of the turbine rotors helps even out the internal temperature distribution within the turbine shells and internal components with respect to the rotor. This helps reduce chances of thermal stress damage, such as rotor bowing and subsequently steam seal damage. By slowly rotating, the turbine rotors stay in a substantially straight and balanced condition during cooling, warming, and standby.

The turning gear assembly typically consists of an electric motor connected to a set of reduction gears that mesh with a corresponding bull gear attached to the turbine rotor. The electric motor torque is converted to slow-speed rotation of the turbine rotor through a series of gear reductions. The turning gear assembly is typically mounted separately from the turbine near the coupling between the steam turbine and generator. The turbine generator coupling will have a bull gear attached to the coupling via bolting or a shrink fit for meshing and engaging the turning gear assembly connection gear.

With the aging of the worldwide power plant fleet, utilities are increasing their focus on providing timely and cost-effective maintenance of their existing equipment, including turning gears. As operating conditions change along with dispatch modes in many current units, past facility turning gear maintenance and inspection practices need to be reevaluated and updated. The increase of units dispatched in a cycling mode has meant heavier use of their turning gears, which they were not designed for, increasing wear. Focus should be placed on potentially more frequent maintenance activities than in the past. In particular, components such as electric drive motors, chain drives, belt drives, oil flow nozzles, and instrumentation should be inspected on a routine basis. Heavier use of the turning gear will warrant more frequent internal visual inspections and could lead to more frequent rebuilds.

Objectives

- To publish a guide summarizing best practices and procedures for the troubleshooting and maintenance of the turning gear systems commonly used by fossil and nuclear utilities in the operation of steam turbine-generator systems

Approach

A technical advisory group (TAG) composed of fossil and nuclear plant representatives from EPRI-member utilities provided input and review of this guide. As part of the underlying development, a survey was sent to selected members of EPRI Program 65 to collect information on current power plant operation and maintenance issues and practices. Additionally, a survey of existing EPRI literature and a search of manufacturer, vendor, and industry databases were conducted to review the latest information available.

Results

The guide addresses activities such as the following:

- General turning gear operations and configurations
- Troubleshooting, including mechanical, electrical, and digital control system data
- Periodic, preventive, and predictive maintenance techniques
- Routine inspection and maintenance criteria
- Jacking, barring, and lift oil systems
- Mechanical and electrical control systems

An appendix to the guide contains a set of data sheets for the recording of measurements and conditions of the turning gear.

EPRI Perspective

EPRI's Steam Turbine-Generators and Auxiliary Systems program develops technologies and guidelines that help plant operators optimize steam turbine and generator equipment life cycles to increase availability, shorten scheduled maintenance outages, and improve steam turbine performance. Research and technical support activities enable power plants to reduce operation and maintenance costs, maximize plant performance, and more effectively implement plant upgrades and asset management strategies.

Keywords

Barring gear
Bull gear
Clash gear
Maintenance
Steam turbine-generator
Turning gear

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001019645

Steam Turbine Generator Auxiliary System Maintenance Guide: Volume 7 (Generator Excitation System) - 1021775

Product Type: Technical Report Date Published: 23-Dec-11

Abstract

Excitation systems are a critical part of the power generation system. They must be capable of providing a reliable excitation current to the generator and respond to system fluctuations while maintaining consistent generator voltage and power factor. Most modern excitation systems use a static or rotating solid-state exciter and include the associated components required to provide regulation and control over voltage and reactive power flow and to enhance power system stability.

The proper operation of an excitation system is critical to maintaining the overall unit availability. This report provides an overview of the most commonly used power plant excitation systems and the recommended predictive, preventive, and outage maintenance practices for their major components. It describes the basic components of excitation systems and how they work and provides guidelines and a checklist to assist plant engineers and maintenance departments in the establishment of an effective maintenance program for excitation systems.

Reports and technical data from the Electric Power Research Institute were researched and discussed with a technical advisory group (TAG). Information on the types of excitation systems in use was provided by utilities and TAG members. The maintenance guidelines were developed from these data and reviewed by the TAG.

Keywords

Brush rigging
Collector rings
Excitation
Excitation transformer
Exciter
Field breaker
Rotating static
Voltage regulator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021775

4

TURBINE GENERATOR OPERATIONAL TOPICS

Guidelines to Generator Operating/Maintenance Decisions following Abnormal Operation – 3002007010

Abstract

Unusual events, such as stator core over fluxing, synchronization out of phase, loss of cooling water, loss of excitation etc., can inflict significant damage and accelerate the aging process of generators. Anecdotal evidence shows that the industry experiences inadvertent energizing of the generator from standstill about every two years. Similarly, generator core over fluxing that may require partial core lamination replacement occurs about every three years. These incidents are caused by equipment failure or human error. Since these events occur infrequently, the operator may not have prior experience with any of them. There is a need to provide operator guidance to recognize unusual events and take appropriate action to avoid them and minimize consequential damage. This guideline covers all types of generators and original equipment manufacturers (OEMs), and describes 27 events in detail.

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Equipment failure
Damage assessment
Generators
Stator-related events
Rotor-related events

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002007010

Turbine Water Induction Protection System: Owner's Guide - 3002003555

Product Type: Technical Report Date Published: 11-Dec-2014

Abstract

Turbine water induction—a damage mechanism in steam turbines—occurs when water or cold steam enters the turbine (or casing) while the turbine is hot. Turbine water induction events can affect any type of generating unit that includes a steam turbine. This report covers conventional steam, combined-cycle, and nuclear generating units.

Water or cold steam can be introduced into a steam turbine through any connecting pipe or drain line. Turbine water induction events can occur during unit startup, load changes, and shutdowns or as a result of equipment failure (that is, valve leakage or level control malfunction). Turbine water induction events are costly, resulting in forced outages and damage to equipment that often requires significant repair or replacement. Damage caused by turbine water induction events includes permanent warping, rubbing of internal components, and thrust bearing failures.

A properly functioning turbine water induction protection (TWIP) system is a strong defense against turbine water induction events. The TWIP system is a passive plant system that monitors the potential for a turbine water induction event and acts to isolate the turbine from the source of water. TWIP system sensors, alarms, valves, and drains are added to the normal functions of other systems associated with the generation and use of steam in an electrical generating unit. The TWIP system monitors, detects, isolates, and disposes of errant water in these at-risk systems.

To ensure proper functionality and effectiveness, the TWIP system needs testing and maintenance at regular intervals with consistent engineering oversight. This report summarizes the functional requirements for the TWIP system and provides a method to assess the status of an existing TWIP system for any generating unit. The report provides technical information and examples to assist operators and plant engineers in developing a list of at-risk systems, identifying TWIP system components, and evaluating relevant procedures. The report also provides information to assist in the identification of weak points in an installed TWIP system. This report includes case studies describing turbine water induction incidents at different types of generating facilities and provides an overview of the implemented corrective actions and mitigating strategies.

Keywords

Inspection programs
Valve testing
Maintenance resources
Attemperator control
Drain isolation
Feedwater heater level control
Steam turbine damage

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003555

Backup Oil System Maintenance Guide - 3002003593

Product Type: Technical Report   Date Published: 24-Nov-2014

Abstract

Several recent failures have occurred in which the main turbine has coasted to zero speed without oil to one or more bearings. This condition causes severe damage to the bearings, journals, and steam path components, requiring significant amounts of time and money to repair. Escape of hydrogen from the generator, with subsequent fire and personnel and equipment risk, can also occur. There are several backup systems in place to prevent this condition that are meant to ensure that when main oil pressure is lost, oil is still delivered to the bearings and hydrogen seals. This report builds on existing guidance contained in past Electric Power Research Institute (EPRI) reports and other relevant sources to develop a comprehensive document covering maintenance and testing of backup oil systems for nuclear, fossil, and combined-cycle applications.

Keywords

Hydrogen
Bearings
Oil
Backup oil systems

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003593

Steam Turbine Supervisory Instrumentation Systems, Volume 1: Reducing Spurious Trips While Maintaining Machine Protection - 3002001267

Product Type: Technical Report Date Published: 25-Nov-13

Abstract

Recently, personnel at a number of utilities operating steam turbine generators have expressed concern with regard to spurious or unnecessary unit trips caused by turbine supervisory instrumentation (TSI). Spurious trips can be costly, and they can cause unnecessary challenges to safety equipment, especially at nuclear units. A better understanding of the function and design basis surrounding TSI as well as how to appropriately use the instrumentation can help the industry to mitigate risks of false negative and false positive events and increase fleet reliability. To support such understanding and help inform those faced with evaluating the costs and benefits of making changes to the existing TSI at a plant, EPRI has developed this technical report. The scope of Volume 1 encompasses six key target areas for which supervisory instrumentation systems play an established role: thrust wear protection, eccentricity, shell expansion, differential expansion, rotor expansion, and vibration. Depending on industry need, future research deliverables will address additional systems and related topics of interest.

Keywords

Differential expansion
Spurious trip
Thrust wear
Turbine supervisory instrumentation
Vibration

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001267

Impact of Minimum Load Operation on Steam Turbines - 3002001263

Product Type: Technical Report Date Published: 5-Nov-13

Abstract

Some utilities, as part of a fleet management strategy, are keeping baseload-design plants that are not competitive for 24/7 dispatch at minimum loads to increase their ability to respond to changing demand. Units being operated this way face some associated risks and may see an additional drop in availability, further exacerbating supply management issues and increasing O&M costs. This report seeks to capture the effects of minimum load operation on steam turbines and provide tools to mitigate the negative impact on power plants. Generators have been excluded from the scope of the report due to the lack of load-driven damage mechanisms identified in the course of investigation.

Background

Due to current economic conditions, including reduced demand, low natural gas prices, and deregulated energy markets, many plants designed as baseload units are unprofitable to run except on a peaking basis. Because large, baseload units are typically slow to start and thus unresponsive to demand on a full cycling schedule, some utilities are choosing to drop load to minimum levels. This allows for faster response to dispatch as well as possibly reduced thermal cycling stress to the equipment.

The project underlying this report is part of the Generation Sector initiative to develop techniques and strategies for flexible operation, which has become a more important component of fleet management in recent years. The results can be used by plant personnel to understand the effects of minimum load, develop a monitoring and protection strategy for a plant, and assist in providing a rationale for or against this style of operation to plant management.

Objectives

- To determine the effects of minimum load operation on steam turbines
- To provide mitigating techniques to reduce the negative impact of minimum load on asset availability

Approach

Initially, an industry survey was launched to establish the state of the industry with respect to minimum load operation. These results and analysis are included in the report. Further investigation was launched into what damage mechanisms are present under minimum load operation or may be accelerated by it. The scope of the investigation also included the impacts of minimum load on cycle chemistry and performance. Mitigating techniques and additional monitoring strategies are included as examples of actions personnel can take to reduce the risk of minimum load operation. Finally, case studies of plants that have operated at extremely low loads are included as examples of what situations may arise and how they can be effectively dealt with.

Results

Although generators suffer a variety of impacts from cycling service, minimum load in itself does not present any additional challenges to the equipment. This report identified several damage mechanisms that may be accelerated by minimum load and operational conditions that can affect the plant. These findings include the following:

- Difficulty maintaining reheat temperatures can arise, depending on boiler design. This can alter the location of the Wilson line region, resulting in erosion in areas previously thought immune.
- Heat rate degradation is unavoidable for a baseload-designed plant at off-design conditions.
- Plant chemistry, all other issues being equal, is unlikely to be made worse simply operating the plant at minimum load rather than at full load.

Application, Value, and Use

This guide will be of use to plant personnel who are asked to aid management in identifying the impact and thus the cost of minimum load operation prior to adopting this strategy. Staff at plants already operating at low loads will find useful techniques that can potentially reduce turbine equipment degradation.

Keywords

Minimum load
Operational flexibility
Steam turbines
Turbine damage mechanisms

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001263

Primer on Flexible Operations in Fossil Plants - 3002000045

Product Type: Technical Report Date Published: 27-Sep-13

Abstract

This primer describes the significant changes that have occurred over the past decade in the duty cycles of fossil power plants and the implications for plant equipment and costs. These changes include the increasing shift in coal-fired and natural-gas-fired power plants from high-capacity-factor, baseloaded operation to various modes of flexible operation, including load-following and low-load operation.

The primer reviews the different types of duty cycles, the stresses that the changes in plant operation put on plant equipment, the potential damage to equipment due to cycling, other effects of cycling, and the mitigation strategies that plant operators are putting into place.

Keywords

Duty modes
Flexible operations
Heat rate reduction
Long-term damage
Outages
Reliability

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000045

Short-Term Shutdown Guidance for Steam Turbine-Generators and Auxiliary Systems - 1021406

Product Type: Technical Report Date Published: 12-Nov-10

Abstract

This report provides guidelines on the methods that utilities should consider to protect operating equipment when it is removed from service for short periods of time. The equipment and systems considered in this report include the steam turbine, generator, exciter, feedwater heaters, and related auxiliaries. The timeframe for this report includes outage periods from a weekend to six months.

Improper layup can cause long-term equipment damage and premature failure. Increased shutdown frequency and duration due to change of operating mode (such as to cyclic operation) and varying system load demands have increased the challenges to planners, operators, and chemists in providing equipment protection during shutdowns. Compounding these problems is the uncertainty of outage durations.

Objectives

Layup procedures depend on the shutdown conditions and requirements. Depending on these conditions and requirements, equipment and units must be maintained in varying states of readiness. No matter what the operating requirements, attention must be paid to protecting the assets and enhancing availability. Plant personnel must be able to choose an appropriate layup procedure for each shutdown condition.

Approach

EPRI and EPRI consultants, with the assistance of a Technical Advisory Group, were tasked with developing a guideline for practices and procedures on short-term layup of fossil turbine, generator, condenser, exciter, and auxiliary systems. Researchers reviewed existing material and conducted discussions with industry personnel, and the Technical Advisory Group reviewed the materials. The report defines layup periods and applicable layup requirements and procedures for components and systems and describes how to react to changing outage conditions.

Results

The guidelines in this report have been developed to provide direction in selecting the appropriate layup procedures for steam turbine-generators and related equipment. This report provides guidance on layup methodology and selection criteria for short-duration shutdowns.

Application, Value, and Use

These guidelines consider various factors (such as design, materials, andsite conditions) for each set of equipment, the operating mode and reason for the shutdown (such as maintenance, dispatch, outage duration, and return-to-service requirements), and the capabilities of each facility to appropriately implement different layup procedures.

EPRI Perspective

These guidelines will help utilities to enhance equipment availability and reliability. They are based on the three guiding principles for equipment protection defined in the Electric Power Research Institute (EPRI) report Cycling, Startup, Shutdown, and Layup Fossil Plant Cycle Chemistry Guidelines for Operators and Chemists (1015657). By applying those principles and the layup procedure options outlined in this report, utilities can select and customize layup practices that will meet the unique needs of their units.

Keywords

Dry layup
Layup
Shutdown
Steam turbine-generator
Wet layup

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021406

Steam Turbine-Generator Technical Equipment/Program Condition Self-Assessment - 1021409

Product Type: Technical Report Date Published: 27-Jul-10

Abstract

The intent of this technical report is to provide a condition self-assessment for fossil and nuclear utility members to determine the overall condition of the steam turbine, electrical generator, and boiler/reactor feedpump turbine equipment.

Objectives

This report is intended for the turbine-generator equipment owner at the fossil or nuclear plant. Performing a self-assessment will include input from operations, performance, maintenance, and others from the plant.

Approach

This condition self-assessment is determined by asking specific technical and programmatic questions on activities performed or problems experienced on the turbine-generator components.

Results

Utility members that perform a self-assessment of the turbine-generator and boiler/reactor feedpump turbine equipment in their plants will have an indicator of the overall condition of the equipment and how well their equipment is maintained.

Application, Value, and Use

The results of a self-assessment can indicate topics or areas that need improvement for the continued, safe operation of the turbine-generator equipment.

EPRI Perspective

Performing a self-assessment for the turbine-generator equipment can challenge plant personnel to determine how other plants are achieving successful equipment programs.

Keywords

Condition monitoring
Feedwater pump turbine
Generator
Self-assessment
Turbine

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021409

Benchmarking Process for a Utility Steam Turbine Generator Organization - 1021382

Product Type: Technical Update Date Published: 19-Jul-10

Abstract

This Technical Update contains a benchmarking survey to assess an organization's or a plant's turbine-generator program. The survey consists of a series of questions structured to capture key elements of a plant's steam turbine-generator program.

Keywords

Aging
Forced outage
Remaining life
System capacity
Turbine-generators

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021382

EPRI Guide to On-line Testing and Monitoring of Turbine Generators - 1016784

Product Type: Software Date Published: 03-Nov-09

Abstract

Guide to on-and off-line testing and monitoring procedures for assessment of the condition of the generator insulation in stator windings, stator core, exciter and rotor windings.

The Guideline provides a list of failure mechanisms for specific generator classes and components, linked to the off-line tests and monitors available for implementation on existing generators for detection of these problems

Platform Requirements

- Windows™ 2000/XP/Vista

Application, Value, and Use

- Optimize on-line monitoring of generators
- Identify most likely failure mechanism
- Select appropriate tests

Keywords

Electrical generator
Failure mechanism
Monitoring
Testing

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001016784

Effects of Flexible Operation on Turbines and Generators - 1008351

Product Type: Technical Report Date Published: 22-Dec-04

Background

As the power industry adapts to new challenges and demands on generating equipment, there is a significant increase in the number of plants that do not operate in a traditional baseload mode. The factors contributing to this trend include deregulation, fuel price changes, addition of new generating units with lower heat rates, changes in demand characteristics to include a greater daily fluctuation, and the increased mandated use of renewable sources. Many steam turbines

and generators in use today were designed for baseload operation and have at least 30 years of operation behind them. Increased flexible operation in the form of cycling, load-following, and peaking increases the rate of damage to critical components in the steam turbines and generators. To avoid costly forced outages and preserve these generating assets, a greater understanding of the effect of flexible operation on these systems is needed.

Objectives

- To consolidate information on the effects of flexible plant operation on steam turbine and generator systems, from both a reliability and performance perspective

Approach

The approach taken in this project is to first assess what the industry data reveal with regard to trends in steam turbine and generator component reliability as plants are operated flexibly. A compilation of qualitative information on steam turbine and generator damage mechanisms that are affected by increased flexible operation supplements this assessment. Additional topics discussed in this report include the effects of very low load operation on thermal performance and operational enhancements to reduce damage from flexible operation.

Results

Industry data over a 20-year period indicate a clear trend toward decreased turbine-generator availability as plants are cycled more frequently, even after accounting for the decreased demand associated with cycling units. Key reported drivers include generator stator and rotor windings, lubrication systems, bearings, and turbine valves. This report discusses all important subsystems and components of the steam turbine and generator with regard to the effects of flexible operation. Aspects of improved operation discussed include variable pressure, improved controls, optimized ramp rate, and generator instrumentation enhancements.

EPRI Perspective

The combined effect of unit aging, increased use of flexible operating modes, and decreased plant staffing level and experience will increase the future risk of costly failures for key systems such as steam turbines and generators. Because these assets remain a critical part of the overall generation portfolio, it is important that plant operators increase their understanding of the relation between operational decisions and consequential effects on equipment. It is likely that many of these effects are initially latent after units are switched to flexible operating modes. This report provides an important overview of the effects of flexible operation on two important plant systems. Future efforts in this area that focus on quantifying the increased risk of failure, or increased rate of component life consumption, would also be useful. It is hoped that greater awareness of damage mechanisms will also provide a basis for modifying operational practices to achieve a compromise between the new dispatching requirements and the need to maintain long-term viability of plant assets.

Keywords

Component Reliability
Steam Turbines
Thermal Performance
Peak Loads
Cycling Operation
Turbine Life Management

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001008351

5
TURBINE CENTERLINE COMPONENTS

Development of a Corrosion-Fatigue Prediction Methodology for Steam Turbine Blades: AISI 403/410 (12%Cr) and 17-4PH Blade Steels - 3002005107

Product Type: Technical Results Date Published: 26-Feb-15

Abstract

The useful life of a steam turbine and turbine outage schedules are often determined by corrosion on the low-pressure (LP) blades and disks in the phase transition zone (PTZ). Developing an effective corrosion damage prediction methodology is important to reducing unscheduled steam turbine outages. This report provides test data and an analytical method for predicting failures associated with corrosion-fatigue for 12% Cr (American Iron and Steel Institute [AISI] 403/410 stainless steel) and 17-4PH steam turbine blades based on inspection at outages.

Background

Although most steam turbines were designed to achieve a lifespan of at least 20 years, many such plants are now more than 40 years old. Small levels of intermittent corrosion can produce significant pits after many years of operation. Factors that affect pit growth rate are known to include feed water quality, turbine operating profile, blade steel chemistry, and the cumulative exposure to corroding salts in an oxygen environment.

It has been more than 30 years since research was initiated to improve the industry's understanding of processes in the so-called *thermodynamic salt zone* and deposit buildup and behavior in the PTZ. Clearly, prior results have not led to a marked improvement in the overall reliability statistics of steam turbines. Development of the technology described in this report provides the plant operator a methodology to define the risk of continued operation with pitted blades.

Objectives

Predicting the location and size of corrosion pits in a blade is not easily accomplished. Corrosion pits form at random locations for the blade as well as the test specimens. It was important to develop a technique to create corrosion pitting of a predetermined size in the necked down region of the fatigue test specimens. This has been accomplished and has been crucial to the support of the ultrasonic fatigue testing program. The data for transition from a pit to a crack have been correlated using the Kitagawa-Takahashi diagram, a presentation of the data that relates the steady stress, cyclic stress, and pit size (depth) to the prediction of fatigue failure. Ultrasonic fatigue testing was an essential aspect of this program. This testing technique makes it possible to accumulate cycles at a rate of approximately 20 kHz. At this rate, one billion (109) cycles are accumulated in less than 14 hours. One billion cycles has been used as the definition for nonprogressive crack or specimen run-out life. All of the data for the survival and failure stress intensity were well represented by the El Haddad refinement to the Kitagawa diagram.

Approach

Developing an approach to consistently and repeatedly produce corrosion pits in blade material test specimens was the first priority of this project. Once accomplished, pits of known size were created at precise locations on fatigue test specimens. Next, samples were loaded into an ultrasonic fatigue test machine and tested until failure at different R-ratio values. Visual evidence of damage development—beginning with individual pits, followed by short cracks emanating from the pits, and ending with large cracks and eventual specimen failure—was recorded for each test sample. The results were then plotted on the Kitagawa-Takahashi diagram to provide a correlating relationship of fatigue failure as a function of pit size, the steady stress, and the cyclic stress range. The diagram enabled the investigators to correlate pit size to the stress level at which time a crack is initiated. With this knowledge, one can predict the critical pit size to failure. Extensive testing has been done in air, vacuum, and two different solution environments. The results of the experimental testing developed under this project were used to assemble a comprehensive prediction methodology that utilities can apply to minimize the risk of failure in steam turbine blades. This research has been limited to two blade steel materials: 12% Cr (AISI 403/410) and 17-4PH.

Results

The model for predicting failure from corrosion-fatigue in LP steam turbine blades was developed jointly by an international team. This report further refines the damage analysis for the progressive corrosion. Ultrasonic fatigue testing has been used to quantify the relationship between corrosion pits and the local stress field necessary to initiate a fatigue crack at a corrosion pit. Crack initiation is a function of pit size, localized steady stress, cyclic stress, and material fracture mechanics properties. Testing has also quantified the crack growth rate as a function of local stress intensity for advancing a crack when the stress intensity occurs within the "Paris" region. The extensive testing of the two blade steel materials also provides guidance to describe the data requirements to extend this methodology to alternative materials.

Applications, Value, and Use

There is a strong financial incentive to achieve maximum life from blades with corrosion-pitted surfaces. However, eventually, continued operation of pitted blades can develop into fatigue cracks and might result in blade failure, with high consequential damage in the turbine. This must be avoided because the repair costs would almost certainly exceed the financial impact of prematurely replacing a blade row. The ideal scenario would incorporate a methodology to define the maximum allowable pit size as a function of pit location on the blade surface. With the application of a suitable safety margin, the blade replacement can be predicted in advance and scheduled at an appropriate time. This approach minimizes capital expenditures while controlling risk to an acceptable level.

Keywords

Blade life prediction	Corrosion pitting	Corrosion-fatigue
12% Cr steel	17-4PH steel	403/410 stainless steel

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005107

Field Demonstration of Low-Pressure Turbine Blade Vibration Monitoring - 1024665

Product Type: Technical Report Date Published: 30-Mar-12

Abstract

This case study documents the use of a commercial blade vibration monitoring system (BVMS) on the final stage of the low-pressure steam turbine of a 425-MW fossil unit. Blade vibration can arise from a variety of causes relating to turbine design and/or operation. Continuous monitoring offers new options for fully exploring all potential root causes of fatigue cracking.

Background

With the increasing size and mass of final-stage blades used in modern low-pressure turbines, the consequences associated with blade liberation are greater. There is therefore a need for more proactive approaches to managing blade cracking. Technical options for vibration monitoring are limited because of the challenges associated with the instrumentation of rotating blades in a condensing steam environment. The blade tip time-of-arrival method employed by commercial BVMSs offers a viable approach to managing risk associated with blade flutter caused by backpressure excursions as well as vibration caused by grid torsional events. These mechanisms, by nature, occur sporadically and therefore require the continuous monitoring capability offered by systems such as the BVMS.

Objectives

The potential causes of low-pressure steam turbine blade fatigue cracking include mechanisms such as aeroelastic flutter, coupled blade-shaft torsional vibration, and inadequate design margins on at- speed natural frequencies relative to turbine speed harmonics. Any monitoring system should be able to address these mechanisms, even if significant blade vibration events are sudden and unpredictable. The capabilities of commercial systems for monitoring blade tip vibration, coupled with results of detailed modeling, provide a viable option for detecting causes of blade vibration and incipient damage. This project provides an end-to-end example of the field application of a BVMS so that plants considering the use of this technology have an improved understanding of the considerations involved.

Approach

This case study involves the use of a commercial BVMS on a 425- MW supercritical coal unit. Installation of the sensors internal to the low-pressure turbine was accomplished in 2010. Long-term monitoring was carried out in 2011. During that time, the BVMS vendor was able to remotely access data to process and assess blade condition. The blade modeling that is critical to interpreting results of the BVMS was accomplished using a commercial finite-element analysis tool. Sample results and analysis scope are provided in this case study report to guide future BVMS technology applications.

Results

This report documents a complete case study of BVMS application. This includes the pre-installation considerations by the host plant and the sensor/cabling installation process performed during a scheduled outage. The implications of BVMS system installation and long-term use are explained in this report and can assist in decision making by potential future BVMS host plants.

One key aspect of successful BVMS application is the bladed-disk vibration modeling that must be completed in order to interpret the raw BVMS data. This report provides a detailed example of this analysis scope and approach and can be used as a guide for future BVMS installations.

Application, Value, and Use

The example provided by this documented case study can guide future strategies used by plant operators faced with managing risk associated with known low-pressure blade cracking. Turbine system engineers should be knowledgeable not only about the technical basis of commercial BVMS, but also the practical issues of installation and long-term use.

Keywords

Blade cracking
Blade flutter
Blade vibration
Vibration monitoring

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001024665

Steam Turbine Monitoring, Inspection, and Repair - 1024780

Product Type: Technical Update Date Published: 15-Feb-12

Abstract

Turbine component degradation and failure continues to result in significant economic impact and turbine unavailability at both nuclear and fossil power generating plants. It is therefore to every operator's advantage to have a formalized program for correction, prevention, and control of steam path damage. Three key pieces of such a program are monitoring and diagnostics, inspection and nondestructive evaluation (NDE), and turbine repair. This brief document summarizes the latest procedures and resources in these three technical areas. The information covers material of importance for those owners performing their own diagnostics and repairs, and should provide an overview to aid those working with outside vendors and OEMs to better understand the available options and procedures, allowing them to make the most effective and economical choices for maintaining the health of turbine equipment.

Keywords

Condition monitoring
Inspection
Performance monitoring
Power plant availability
Steam turbines
Turbine repair

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001024780

Locations and Mechanisms of Turbine Steam Path Damage - 1024749

Product Type: Technical Update Date Published: 14-Feb-12

Abstract

Given the multitude of turbine damage mechanisms and the many features they have in common, it can be difficult to absorb important technical information quickly from the traditional report format. This poster supplements existing EPRI documentation by providing a holistic view of all mechanisms.

Keywords

Damage mechanisms
Poster
Steam path damage
Steam turbine

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001024749

Field Guide: Turbine Steam Path Damage - 1024593

Product Type: Technical Report Date Published: 12-Dec-11

Abstract

Steam path damage, particularly of blades, has long been recognized as a leading cause of steam turbine unavailability for large fossil fuel plants. Damage to steam path components by various mechanisms continues to result in significant economic impact domestically and internationally. Electric Power Research Institute (EPRI) Report TR-108943, Turbine Steam Path Damage: Theory and Practice, Volumes 1 and 2, was prepared to compile the most recent knowledge about turbine steam path damage: identifying the underlying mechanisms, determining their root cause, and choosing immediate and long-term actions to lessen or prevent recurrence of the problem. This field guide provides a pocket reference based upon the content of the report.

Objectives

Damage to steam path components by various mechanisms continues to result in significant economic impact domestically and internationally. For many observations of damage, either the root cause is not determined, or it is determined incorrectly. Usually, the final failure is remote enough from the events or, more normally, series of events that the true cause is obscured. As a result, corrective actions taken have varying success rates, and the same types of damage often reoccur.

As users push for more economic operation of units, a key goal is to move to longer periods between planned turbine outages. Reaching this goal will require careful analysis of damage, determination of the underlying mechanism, correction of the root cause, and choice of the appropriate actions to avoid reoccurrence. This field guide provides guidance on addressing the contributing causes of each damage mechanism to help eliminate repeat failures.

Approach

This field guide was developed from the content of EPRI Report TR-108943.

Results

Failures of blades and discs in fossil and nuclear turbines represent a serious loss of availability for power generation suppliers and other energy suppliers worldwide. Other problems such as deposition onto blade surfaces result in efficiency losses that restrict operation, may result in reduction of maximum capacity, and result in significant economic penalties.

A formalized company-wide program for correction, prevention, and control can minimize turbine-related problems. Events can emanate from inadequate initial design, poor operation and maintenance, cycle chemistry environments, and lack of proper management support.

This guide provides brief background information and fundamentals on the operating environments, basic chemistry, and materials. The degradation mechanisms detailed in Volume 2 of TR-108943 are captured in this field guide. For each mechanism, the focus is on helping the user to identify the mechanisms of failure and the contributing causes and on providing appropriate mitigating actions.

Application, Value, and Use

Steam path damage occurs in the low pressure turbines in nuclear plants and in the high-, intermediate-, and low-pressure turbines of fossil plants. The information and comprehensive approach presented in this field guide will help organizations to approach and achieve world class performance.

EPRI is pursuing a series of field manual-style projects that seek to reformat EPRI and industry knowledge into a more user-friendly format. This guide is designed to be portable and includes information useful for personnel seeking to identify failures in the field. By creating guides in a more portable format that are graphics intensive, while retaining references to more in-depth sources, EPRI believes that the research done by the Institute will be made more available and useful to plant staff.

Keywords

Contributing causes
Failures
Fossil plant
Nuclear plant
Steam path damage
Turbine

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001024593

Steam Turbine On-Line Blade Condition Assessment - 1014143

Product Type: Technical Report Date Published: 30-Apr-08

Background

Recent upgrades, retrofits, and replacements of low-pressure (LP) rotors have resulted in longer, more massive LP blades being deployed in these advanced turbine steam-path designs. Recent failures of LP turbine blades have demonstrated that the entire turbine-generator set is at risk if one or more large blades crack and separate, creating a massive rotating unbalance. On-line monitoring of blade condition can reduce the risk of blade failure, particularly in situations where the initiation and propagation time is less than the inspection interval. Historically, methods such as strain gage telemetry have been valuable in diagnosing the root cause of repeat blade failures. The emphasis in this report is field-ready technology that is sufficiently robust to be used long term and that requires a minimum of data processing effort by the plant staff.

Objectives

- To research commercially available and emerging technology for on-line condition assessment of large steam turbine blades with concentration on technologies that can detect changes in blade vibrational characteristics associated with propagating cracks
- To report on industry experience with currently available on-line blade monitoring technology

Approach

The project team used finite element modeling and analysis in combination with threedimensional fracture analysis to assess the effects of crack propagation on measurable L-0 blade characteristics. The measurable L-0 blade characteristics included change in natural frequencies, change in blade-tip clearance, and change in tangential and axial lean for the blade tips. The analyses were performed on representative models in freestanding, continuous-tie, three-blade group, and five-blade group configurations. For each configuration, crack initiation site locations were determined, and the effect of crack growth at these initiation sites on model behavior was investigated. Commercially available technologies that could be deployed individually or synergistically for on-line condition monitoring of large steam turbine blades were evaluated, and applicable field experiences were discussed to support the conclusions. Emerging technologies were investigated for suitability in steam turbine blade on-line condition monitoring applications. Noncontacting blade-tip vibration monitoring technologies, micro-electricalmechanical systems-based blade vibration monitoring technologies, energy harvesting technologies, and wireless data communication for condition monitoring were included in the investigation.

Results

Of the measurable blade characteristics evaluated, change in blade lean demonstrated the highest sensitivity to all crack types investigated, with change in tip clearance being a poor indicator of blade damage resulting from root cracks and airfoil cracks. Field measurement experiences and experimental exercises indicate that passive eddy current (variable-reluctance) blade-tip sensors are the most practical and mature technology for this application. A review of emerging technologies shows that eddy current sensors, optical sensors, and capacitive sensors are being evaluated for various turbomachinery applications. More development is required for microelectrical-mechanical systems technology or energy-harvesting technology to be useful for steam turbine blade on-line monitoring.

EPRI Perspective

High-cycle fatigue cracks can rapidly initiate in large steam turbine blades under conditions of excessive vibration or when the material is degraded as a result of pitting or fretting. Inspection intervals have been increasing as plants seek to optimize maintenance. However, the remaining life of a cracked turbine blade can be shorter than the inspection interval, which represents a risk. The safety and risk potential for damage to the plant resulting from the loss of a large blade is significant, based on experience from several incidents worldwide over the last two decades. The trend toward the use of larger, more massive freestanding L-0 blade designs increases the consequential damage caused by fatigue fracture. Exploitation of on-line condition assessment technology for large steam turbine blades can reduce the risk of blade failure, particularly in situations where the initiation and propagation time is less than the inspection interval.

Keywords

Blade vibration monitoring
Condition monitoring
Low-pressure turbine blades
On-line condition assessment
Steam turbine blades

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014143

Steam Turbine Blade Failure Root Cause Analysis Guide - 1014137

Product Type: Technical Report Date Published: 31-Mar-08

Abstract

Steam Turbine Blade Failure Root Cause Analysis Guide is a concise reference written for operators to plan and conduct an investigation into the most probable causes of a steam turbine blade (bucket) failure. The report provides both an overview and step-by-step approach to identifying the damage mechanisms most common to turbine blade failures. It proceeds to show how damage mechanisms are related to the operating history prior to the blade's failure and how they are evaluated to establish their role as principal (root) causes versus secondary contributors.

Objectives

The measure of success in any blade failure investigation is the prevention of a repeat incident. The process of investigation is complicated by the fact that it involves the coordination of multiple activities and specialized engineering disciplines. This report is meant to provide a turbine operator with a roadmap of how a typical investigation should proceed, when specialists should be involved, what they should contribute, and how the evidence is used to establish corrective action, either with the original equipment supplier or a qualified third party.

Approach

The methodology and approach described in this report are derived from an experience base of more than 350 independent failure investigations. Examples are included as an appendix to demonstrate how certain critical information derived from the method of investigation was applied to diagnose the most common types of failures.

Results

Over the life of every steam turbine, millions of dollars are spent on proper maintenance, efficient operation, and routine repairs. Blade failures—from premature cracking to the in-service catastrophic breakdown of the components—represent the single greatest threat to the planned maintenance and reliable operation of these large units. Correct and timely diagnosis of the root cause(s) is fundamental to managing the immediate problem and establishing a long-term strategy for sister units operating with the same blade.

Application, Value, and Use

In a competitive market, operators do not have the luxury of treating blade failures as random occurrences, with a replacement in kind substituting for a serious attempt to fully understand what precipitated the breakdown of a specific blade design. Statistics and experience show that if a turbine blade reliability issue remains uncorrected, it will persist. The associated downtime and lost power production associated with repeat failures substantially outweigh the cost and time spent establishing the root cause and a permanent refurbishment or replacement strategy.

EPRI Perspective

The report is meant to remove some of the black box that surrounds the investigation of unexpected blade problems. It focuses on identifying what, when, and how critical information is used to minimize speculation and form a technical consensus from which a corrective strategy with a high probability of success can be devised.

Keywords

Fatigue
Finite element analysis
Root cause analysis
Steam Turbines

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014137

Turbine Steam Path Damage: Theory and Practice, Volume 1: Turbine Fundamentals - TR-108943-V1

Product Type: Technical Report   Date Published: 20-Aug-99

Abstract

Historically, most treatises about steam turbines have concentrated on thermo-dynamics or design. In contrast, the primary focus of this book is on the problems that occur in the turbine steam path. Some of these problems have been long known to the industry, starting as early as A. Stodola's work at the turn of the century in which mechanisms such as solid particle erosion, corrosion and liquid droplet damage were recognized. What we have tried to do here is to provide, in a single, comprehensive reference, the current state of knowledge for major forms of steam path damage. For each problem, topics covered include features (microscopically and macroscopically) of the damage, common locations and susceptible units, mechanism, root causes, determining the extent of damage, repairs and immediate actions to be taken, and longterm actions. There are strong motivations for directing the focus to steam path problems. Failures of blades and discs in fossil and nuclear turbines represent a serious loss of availability for power generation suppliers and other energy suppliers worldwide. Other problems such as deposition onto blade surfaces result in efficiency losses that restrict operation, may result in reduction of maximum capacity, and result in significant economic penalties. Three strongly held philosophical beliefs underlie the approach taken in this book. First, that understanding of the mechanism and root cause of each incidence is of paramount importance to the permanent alleviation of the problem. Second, that by understanding what causes these problems to occur, it should be possible to anticipate their development, monitor evolving "precursors" in the unit, and take early action to avoid a significant condition from occurring. This will become particularly important to turbine operators as the period between planned overhauls increases, thus placing a premium on detecting developing damage without opening the turbine. Third, a formalized company-wide program for correction, prevention, and control can minimize turbine-related problems. Events can emanate from inadequate initial design, from poor operation and maintenance, cycle chemistry environments, and lack of proper management support. It is clear that more than just proper technical guidance will be necessary to reduce the costs associated with turbine damage. Over the last twenty years, many people and groups have influenced our thinking on this very diverse topic; while a complete listing would cover many pages, a sample provides a flavor for the breadth of their contributions.

Many excellent papers and design text books have been written on the subject of steam turbines, including those written by Wilfred Campbell, Ken Cotton, Ralph Ortolano, M. Prohl, Neville Rieger, J. Kenneth Salisbury, Bill Sanders, George Silvestri, and A. Stodola to name just a few. Over the last 10 years, tremendous support has also been available internationally, and many individuals and organizations have assisted in developing solutions to most of the known steam path failures. Particular acknowledgment is made of Walter David (Siemens), Joseph Denk (ABB), Alan Hesketh (Alstom), Stuart Holdsworth (GEC), Markus Speidel (Swiss Federal Institute of Technology), and Bobby Svoboda (ABB).

Keywords

Erosion Corrosion
Power Plant Availability
Steam Turbines
Thermodynamic Properties
Thermodynamics

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-108943-V1

Turbine Steam Path Damage: Theory and Practice, Volume 2: Damage Mechanisms - TR-108943-V2

Product Type: Technical Report Date Published: 20-Aug-99

Abstract

Historically, most treatises about steam turbines have concentrated on thermo-dynamics or design. In contrast, the primary focus of this book is on the problems that occur in the turbine steam path. Some of these problems have been long known to the industry, starting as early as A. Stodola's work at the turn of the century in which mechanisms such as solid particle erosion, corrosion and liquid droplet damage were recognized. What we have tried to do here is to provide, in a single, comprehensive reference, the current state of knowledge for major forms of steam path damage. For each problem, topics covered include features (microscopically and macroscopically) of the damage, common locations and susceptible units, mechanism, root causes, determining the extent of damage, repairs and immediate actions to be taken, and longterm actions. There are strong motivations for directing the focus to steam path problems. Failures of blades and discs in fossil and nuclear turbines represent a serious loss of availability for power generation suppliers and other energy suppliers worldwide. Other problems such as deposition onto blade surfaces result in efficiency losses that restrict operation, may result in reduction of maximum capacity, and result in significant economic penalties. Three strongly held philosophical beliefs underlie the approach taken in this book. First, that understanding of the mechanism and root cause of each incidence is of paramount importance to the permanent alleviation of the problem. Second, that by understanding what causes these problems to occur, it should be possible to anticipate their development, monitor evolving "precursors" in the unit, and take early action to avoid a significant condition from occurring. This will become particularly important to turbine operators as the period between planned overhauls increases, thus placing a premium on detecting developing damage without opening the turbine. Third, a formalized company-wide program for correction, prevention, and control can minimize turbine-related problems. Events can emanate from inadequate initial design, from poor operation and maintenance, cycle chemistry environments, and lack of proper management support. It is clear that more than just proper technical guidance will be necessary to reduce the costs associated with turbine damage. Over the last twenty years, many people and groups have influenced our thinking on this very diverse topic; while a complete listing would cover many pages, a sample provides a flavor for the breadth of their contributions.

Many excellent papers and design text books have been written on the subject of steam turbines, including those written by Wilfred Campbell, Ken Cotton, Ralph Ortolano, M. Prohl, Neville Rieger, J. Kenneth Salisbury, Bill Sanders, George Silvestri, and A. Stodola to name just a few. Over the last 10 years, tremendous support has also been available internationally, and many individuals and organizations have assisted in developing solutions to most of the known steam path failures. Particular acknowledgment is made of Walter David (Siemens), Joseph Denk (ABB), Alan Hesketh (Alstom), Stuart Holdsworth (GEC), Markus Speidel (Swiss Federal Institute of Technology), and Bobby Svoboda (ABB).

Keywords

Erosion Corrosion
Power Plant Availability
Steam Turbines
Thermodynamic Properties
Thermodynamics

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-108943-V2

6
TURBINE METALLURGY AND STEAM CHEMISTRY

Steam Turbine Casing and Valve Body Repair Guidelines - 3002001473

Product Type: Technical Report Date Published: 14-Dec-13

Abstract

Today's flexible mode of operation can result in damage to heavy-section components, such as steam turbine and valve casings. Thus, owners and operators are often faced with repairing a critical component. This report is part of a set of documents that address the key areas in the asset management of steam turbine casings and valve bodies—nondestructive evaluation and damage detection, repair, and life assessment.

This report provides the tools for utilities to make high-quality engineered repairs. The report provides a series of roadmaps and the decision tools necessary to make informed judgments regarding selection of a well-engineered repair (which might include leaving damage as is) for these critical components. Additionally, a series of appendices provides substantial background information on material specifications and options for weld repairs and mechanical repairs. The intent of this report is to provide a concise, clear approach to the required repair solution after nondestructive evaluation has been performed and damage has been found and analyzed.

Keywords

Damage assessment
Life management
Nondestructive evaluation
Turbine casings
Valve bodies
Weld repair

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001473

Program 65 Metallurgical Cross-Reference Guidebook - 1021781

Product Type: Technical Report Date Published: 11-Nov-11

Abstract

Over a period of years, the Electric Power Research Institute's Steam Turbine-Generator and Auxiliary Systems program has developed numerous maintenance guides, research products, and handbooks focused on steam turbines, generators, and associated auxiliary equipment. Many of these reports include data on the metallurgical properties of this equipment, and some are specifically focused on collecting metallurgical data on specific systems. However, many of these data are spread over a large number of guides, making it difficult for readers to locate the appropriate information when it is needed. This cross-reference report seeks to collect and organize some of these data so that the reader can find appropriate reference material regarding metallurgical data.

Keywords

Metallurgy
Steam turbine
Turbine bolting
Turbine buckets/blades
Turbine rotors
Turbine valves

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021781

International Steam Turbine Valve Metallurgy Guide - 1023066

Product Type: Technical Report Date Published: 27-Sep-11

Abstract

This report reviews the state of the art in materials usage for steam turbine valves manufactured and used in Europe and looks at materials options for the higher-temperature applications now being considered for advanced high-efficiency power plants. The emphasis is on valves for extreme service conditions (high temperatures, pressures, and flow rates), of which bypass valves represent a good example. Some consideration is also given to degradation and failure mechanisms. In focusing on practices outside the United States, the report complements EPRI report 1016786, U.S. Steam Turbine Valve Metallurgy Guide, published in 2009.

Keywords

Alloys
Martensitic steels
Materials
Metallurgy guide
Ni-base alloys
Steam turbine valves

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001023066

Metallurgical Guidebook for Steam Turbine Rotors and Discs, Volume 1: Chemistry, Manufacturing, Service Degradation, Life Assessment, and Repair - 1017612

Product Type: Technical Report Date Published: 23-Dec-09

Abstract

This guide is a compilation of information concerning steam turbine rotors and discs. Due to the variety of operating temperatures and conditions involved, factors such as material composition, manufacturing and heat treatment condition methods, and property requirements may differ from one steam turbine to another. Specifically, this guide addresses turbine rotor and disc materials used, vintages, manufacturing history, quality conditions, and chemical and mechanical properties, and it provides utility engineers with the background necessary to perform component integrity assessment and remaining life prediction.

Objectives

Steam turbine engineers are constantly faced with having to determine proper inspection intervals for turbine rotors and discs. Associated with these inspections is the need to properly assess a component's condition and, based on the assessment, predict the next inspection interval. This guide provides engineers with tools they will need to perform accurate condition assessments.

Approach

This report used information gathered from previously published EPRI reports, conference proceedings, and books. It has been updated to include the newest materials and designations now being used in the construction of higher-efficiency power plants. The goal of this two-volume guide is to provide the reader with the tools and data to perform condition and life assessments for steam turbine rotors and discs.

Results

This guide places more than four decades of research and development by the Electric Power Research Institute (EPRI) and others in the area of steam turbines at the fingertips of utility engineers. When faced with performing condition assessment of a rotor or disc, engineers can find in this metallurgical guideline specific details, methodologies, and materials properties to help them understand and predict the condition and remaining life of a component. This report is an update of the 2004 version (1004861) and now includes details on welded rotor construction and design philosophy, new materials, and European specifications.

Application, Value, and Use

This metallurgical guideline is the first of a two-volume set on steam turbine rotors and discs. Volume 1 provides a comprehensive summary of 1) rotor and disc development and corresponding chemistry evolution from the 1940s through the 2000s; 2) steel melting, refining, and manufacturing methods; 3) design philosophies of U.S. and European turbine manufacturers; 4) testing methods for determining forging quality; 5) in-service degradation mechanisms and their effects on various properties; 6) remaining life assessment methods; 7) weld repair evaluation methods; and 8) material sampling and testing techniques used to obtain necessary properties for service-run rotors and discs. Volume 2 of this guidebook (1009766) is a materials property database for high-pressure/intermediate-pressure and low-pressure rotor materials to assist turbine maintenance engineers in carrying out current condition and remaining life assessment tasks. Together, these two volumes provide utility engineers with the necessary tools to accurately assess the condition of a rotor or disc.

EPRI Perspective

More than four decades of EPRI research and development toward improving steam turbine rotor and disc life have been conducted. This guideline reviews much of the research and offers utility engineers ready access to information necessary for performing remaining life or condition assessments. This guideline provides not only the methodologies to perform such assessments but also the materials property data required to complete the assessments. Finally, this guideline includes a comprehensive list of reference data and citations for use by utility personnel.

Keywords

Disc materials
High-pressure/intermediate pressure (HP-IP) turbine
Low-pressure (LP) turbine
Rotor materials
Steam turbine materials
Steam Turbines

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001017612

Metallurgical Guidebook for Steam Turbine Rotors and Discs, Volume 2: Materials Property Database for HP-IP and LP Rotors - 1019779

Product Type: Technical Report Date Published: 23-Dec-10

Abstract

As the power plants are aging, many of the components have either surpassed or are nearing their intended design lives. Due to the range of temperatures the steam turbine components areexposed to, material composition, manufacturing and heat treatment methods, and property requirements vary widely. Having the proper knowledge about the vintage, manufacturing history, quality conditions, chemical and mechanical properties, etc., of the rotors and discs become vital when decisions about run, repair, or replace are made. Several options on the methods and degree of sophistication are available to perform inspections, materials evaluations, integrity assessment and the remaining life prediction. This metallurgical guidebook is intended for the power plant personnel to provide them the necessary background information on HP-IP, LP rotor and disc materials used in USA and Europe; evolution of the various compositions over several decades, forging manufacturing methods and their influence on the quality of the forgings, material degradation mechanisms in service, and remaining life assessment methods.

Objectives

Steam turbine engineers must constantly determine the proper inspection intervals for turbine rotors and discs. Associated with these inspections is the need to properly assess a component's condition and, based on the assessment, predict the next inspection interval. This guide provides engineers with the information that they will need to perform accurate condition, integrity, and remaining life assessments.

Approach

This report uses information gathered and summarized from previously published EPRI reports, conference proceedings, books, and journal articles. The goal of this report is to provide the tools, material properties, and methodologies necessary to perform condition and remaining life assessments for steam turbine rotors and discs. This report is an update of the original volume 2 report (EPRI Report 1009766). This current guide has added mechanical property data from 12 additional HP-IP and four LP chemical compositions including steels developed and tested in the past 10 years which were not in the original report. More than 80 new database pages have been added to augment the original guide for these materials.

Results

This guide makes more than three decades of research and development by EPRI and others in the area of steam turbines easily available to utility engineers. When performing condition assessment of a rotor or disc, users of this metallurgical guideline have specific details methodologies, and material properties to help them understand and predict the condition an remaining life of a component.

Application, Value, and Use

This metallurgical guideline is the second of a two-volume set on steam turbine rotors and discs. Volume 1 in this series (EPRI Report 1017612, Metallurgical Guidebook for Steam Turbine Rotors and Discs: Volume 1: Chemistry, Manufacturing, Service Degradation, Life Assessment,and Repair) provides a comprehensive summary of the following:

- Rotor and disc development and corresponding chemistry evolution from the 1940s through the 2000s
- Steel melting, refining, and manufacturing methods
- Design philosophies of U.S. and European turbine manufacturers
- Testing method for determining forging quality
- In-service degradation mechanisms and their effects on various properties
- Remaining life assessment methods
- Weld repair evaluation methods
- Material sampling and testing techniques used to obtain necessary properties for service-run rotors and discs

This volume is an update of an earlier Guidebook produced by EPRI in 2004 (EPRI Report 1009766). It contains a material property database for HP-IP and LP rotor materials to assist turbine maintenance engineers in carrying out current condition and remaining life assessment tasks. Together, these two volumes provide the utility engineer with the necessary tools to accurately assess the condition of a rotor or disc.

EPRI Perspective

EPRI has conducted more than three decades of research and development to improve steam turbine rotor and disc life. This guideline reviews much of this research and offers the utility engineer ready access to the information necessary for performing remaining life or condition assessments. It provides not only the methodologies to perform such assessments, but also the material property data required to complete the assessments. Finally, this guideline contains a comprehensive list of reference data and citations for use by utility personnel.

Keywords

Discs
HP-IP turbine
LP turbine
Remaining life
Rotors
Steam turbine

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001019779

7
GENERATOR STATOR RESEARCH

Maintenance Guidelines for Generators Used in Simple and Combined Cycle Plants - 3002003590

Product Type: Technical Report Date Published: 17-Dec-14

Abstract

Gas-fired combustion turbine plants, which were originally designed for base load operation, are now operated primarily in two-shift cycling mode. Cycling has the effect of accelerating aging factors for generator components. Generators that have been forced to adapt to a cycling mode of operation may require major maintenance, including rewinding or replacement of rotors and stators. This report provides maintenance guidelines for air and hydrogen cooled generators supplied by major US, European, and Asian generator original equipment manufacturers (OEMs) and their licensees, operating in 50 and 60 Hz systems, in single and combined cycle gas fired combustion turbine power plants.

The report identifies components that need to be monitored, inspected, repaired, and replaced over the lifetime of a plant and discusses the timing and duration of maintenance activities. It describes the failure mechanisms of stator cores, stator windings, and rotor mechanisms and covers generator access and handling issues related to removal, lifting, lay-down, and transportation at typical configurations of single and combined cycle plants combustion turbine plants.

Program

2014 Program 65
Steam Turbines-Generators and Auxiliary Systems

Keywords

Combined Cycle
Combustion turbines
Failure mechanisms
Generators
Maintenance

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003590

Early Detection of Flow Restriction in Stator Generator Cooling Water Systems - 3002003591

Product Type: Technical Report Date Published: 14-Dec-14

Abstract

Flow restrictions inhibit stator bar cooling and result in increased stator bar temperatures. Because there can be multiple reasons behind an increase in stator bar temperatures, considerable effort is often required to pinpoint the cause. Limited availability of monitoring instrumentation further complicates the issue. Typically, stator bar temperatures are measured by stator resistance temperature detector (RTD) values and thermocouples that measure the individual bar cooling outlet water temperature. It is critical that the root cause of the increased stator winding temperatures be identified as soon as possible—particularly in the case of flow restriction. Early intervention may prevent unit overheating, derating, and costly chemical cleaning, thus eliminating or reducing the risk of lost revenue or generator damage. This report describes online capable methods—including advanced pattern recognition (APR) and thermal-hydraulic models—to detect the onset of flow restrictions in water cooled stator windings and to provide an ongoing measure of the degree of degradation. The report also details a pilot application of the models for in-service monitoring.

Background

The stator cooling water system is one of the most critical systems in a modern power plant. A number of challenges, however, confront the reliable operation and maintenance of these systems. Copper corrosion products can plug the hollow strands of the stator-winding coil and cause flow restrictions that reduce cooling capacity. If the cooling capacity is sufficiently impaired and temperatures exceed design parameters, the unit must be cleaned to avoid damage to the windings. Where online cleaning is not possible, the unit must be shut down for cleaning and repair. In extreme cases, the degradation of the stator cooling water system can lead to plant failures. Because power generators continue to experience stator cooling water flow restrictions, it is essential that system operators recognize plugging problems with sufficient lead time to allow for appropriate, cost-effective corrective action.

Objectives

To develop and apply APR and thermal-hydraulic models for the earliest possible detection of flow restriction in water-cooled stator windings.

Approach

APR is a proven technique for monitoring complex interrelated systems of instrument signals in order to provide very sensitive detection and characterization of abnormal changes in the data. APR models can be used to define how a system should be operating in a manner similar to using thermal-hydraulic (heat and mass balance) models to define the relationships between a set of system parameters. Both approaches have strengths for early detection of flow restriction in water-cooled stator windings. The thermal-hydraulic model developed for this project is a fouling factor model, which requires a special fouling prediction model plug-in for software implementation. The APR models developed include ones for stator bar water exit temperature, parallel ring and bushing water exit temperature, heat exchanger water temperature, stator cooling water pressure and flow, end winding temperature, and conductivity.

Results

APR models are quickly and easily calibrated for a variety of generator types, configurations, and aging conditions, requiring only a clean set of normal operating data to learn all of the normal variations on the data. The complex heat and mass transfer relationships expressed within the data are captured as a set of patterns that define variations in the data statistically. Using APR methods, it is not necessary to develop approximate mathematical models since the actual relationships are expressed directly by interrelationships within the data itself. A primary advantage of the APR method is that abnormal signals can be identified early on, and their abnormalities can be characterized even while each signal is operating within its normal range. APR models can also prove to be more sensitive to abnormal behavior than thermal-hydraulic models, which are often formulated with simplifying approximations.

The primary disadvantage of APR models is that they will accurately reproduce only those configurations and operating conditions for which they are expressly trained, that is, for which representative patterns are included in the calibration data. This means that an APR model will not extrapolate accurately to represent configurations and conditions other than those in the data used to calibrate the model and should not be used for monitoring such conditions. In contrast, a thermal-hydraulic model explicitly includes the heat and mass balance relationships present in the data and can often be used more reliably to monitor configurations and conditions somewhat different from the data used to calibrate the model.

Software systems exist today that can operate both types of models in parallel so that the results can be combined for a high-confidence diagnosis of the actual root cause for high-temperature indications in stator bars. The thermal-hydraulic and APR models described in this report have been deployed for in-service monitoring of a Westinghouse 1450 MVA generator at Duke Energy's McGuire Nuclear Station, Unit 2, in Huntsville, North Carolina. The pilot application is described in this report.

Applications, Values, and Use

Online thermal-hydraulic and APR methods differentiate between stator winding temperature changes caused by flow restriction and other causes. These methods alert system operators when flow restriction reaches a threshold condition that can be detected reliably on-line and help in determining the degree of degradation. Unfortunately, there is no one single definitive method to quantify flow restriction in a single hollow conductor or group of conductors so as to ensure that local hot spots are not developing in the stator core. Thus, information on models for early detection of flow restriction in stator cooling water systems should be expertly reviewed in context of the individual generator design when planning for maintenance or refurbishment. Related EPRI research includes *Turbine Generator Auxiliary System Maintenance Guide Volume 4: Generator Stator Cooling Water System: 2013 Update* (report 3002000420), which provides a comprehensive compilation of EPRI's research on best practices for operation of generator stator cooling water systems.

Keywords

Advanced pattern recognition (APR)
Generator stators
Online monitoring
Thermal-hydraulics model

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003591

Guide for Stator Winding Coil Insulation Repair - 1014909

Product Type: Technical Report Date Published: 11-Mar-08

Abstract

Generator and motor stator winding insulation occasionally are subjected to localized physical damage. Damage can occur either from debris striking the winding during operation or during a maintenance outage. Machine inspection, maintenance, and repair expose stator winding insulation to inadvertent damage. Damage becomes even more acute during a stator re-wedge operation where old wedges must be removed from the slot and new ones installed on exposed insulation surfaces. Removal and re-insertion of endwinding blocking and ties that may have become loose, or have abraded the groundwall insulation, also can cause damage away from the core. Repairing certain types of localized stator winding insulation damage in situ is often possible. This report provides guidance on making such localized repairs.

Objectives

This report focuses on repairing bars or coils in form-wound stators. Such stators are usually rated 3.3 kV and above.

Approach

The project team investigated the repair of certain types of localized stator winding insulation damage in situ. As part of the project, four types of damage were inflicted on 13.8-kV coil endwindings and three types of damage on the stator slot area. The repair for each type of damage is described. To assess repair effectiveness, insulation resistance, polarization index (PI), and partial discharge were measured before and after each repair. The team also applied an ac hipot test to each repair. After all seven repairs were made, coils were ac hipot tested up to 40 kVrms (the normal commissioning hipot level for a stator winding is 28.6 kVrms).

Results

The report describes how to determine when coil insulation damage is reparable, then provides general guidance for groundwall insulation repair. Four case studies of coil repair procedures are presented.

Application, Value, and Use

Basic principles are provided for repairing insulation damage both in stator core slots and in endwindings. The procedures described in this report are applicable to motor, hydrogenerator, and turbine generator stators and provide a reasonable expectation of reliable service for the remainder of the affected unit's original expected life.

EPRI Perspective

This report focuses on relatively minor localized mechanical damage. In many cases, damage can be so severe that it is not reparable using the procedures described here. In these cases, there are several other options available, all of which are beyond the scope of this report. Ranked from most to least expensive, the options are rewind the stator; replace the bar; perform a half coil splice, assuming a multi-turn coil winding; or cut out the bar or coil from the stator circuit.

Keywords

Stator winding bar repair
Stator winding damage
Temporary repair

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014909

Electrochemical Corrosion Potential (ECP) of Hollow Copper Strands in Water Cooled Generators - 1014813

Product Type: Technical Report Date Published: 28-Mar-07

Abstract

The purpose of this work was to confirm that the electrochemical corrosion potential (ECP) of copper strands in a generator stator cooling water (SCW) system serves as an indicator of system health and can provide an early warning of corrosive conditions. The ECP of copper is expected to be relatively low in a low dissolved oxygen ("low-DO") system operating within specification and to be relatively high for a normally "high-DO" system. Low-DO is defined as <50ppb dissolved oxygen, and high DO is defined as >2ppm. Intermediate ECP values are expected to be indicative of dangerous (upset) conditions in which copper oxides and soluble copper are released from the strand surfaces and deposit preferentially in downstream locations. These deposits may then cause plugging of the strands or clogging of the strainers.

Objectives

This report should be of interest to plant chemists and those who are responsible for maintenance and repair of water-cooled electric generators. The report describes how to monitor the ECP of copper in SCW systems and how to use ECP data to warn of dangerous operating conditions that could lead to strand plugging, overheating, and destruction of the stator bar.

Approach

Tri-State Generation & Transmission's Craig Station Unit 3, which operates a normally high-DO SCW system, and Tarong Energy's Tarong Power Station Units 1 and 3, which operate normally low-DO SCW systems, hosted this work. Investigators fitted instruments to monitor ECP, dissolved oxygen, dissolved hydrogen, particle concentration, and temperature of the flowing water sample in a sidestream flow loop attached to the SCW system at each plant. Operating parameters also monitored included gross load and SCW temperature differential, pressure differential, and specific conductivity. The investigators compared these variables and, where possible, correlated them. Results of this work were not inconsistent with previously proposed mechanisms of plugging.

Results

The experimental work was performed in electric generators operating with normally high-DO or low-DO SCW systems. Volume 1 of this report details the results and findings for a high-DO system, and Volume 2 for a low-DO system. During experiments performed in the normally high-DO SCW system, the DO concentration never fell outside of the range specified by the original equipment manufacturer (>2 ppm) so increases in copper oxide particle concentrations were neither expected nor observed. In contrast, the DO concentration in a normally low-DO SCW system was deliberately cycled between low-DO and intermediate-DO conditions. In this case, copper oxide particle concentrations in the SCW were expected to increase; but, in fact, increases were not observed. Nevertheless, the results gathered in both generator SCW systems suggest that monitoring the ECP of copper strands can serve as an indicator of system health. Based on the preliminary data gathered, dangerous conditions in a normally high-DO system would be marked by ECP values of <93 mV (Ag/AgCl, 1M KCl) [or <305 mV (Standard Hydrogen Electrode—SHE)]. Similarly, dangerous conditions in a normally low-DO system would be marked by ECP values of >43 mV (Ag/AgCl, 1M KCl) [or >266 mV (SHE)].

Application, Value, and Use

The data generated in this work are preliminary in nature but confirm that ECP is affected not only by dissolved oxygen concentration but also by prior exposure history. Further studies are recommended to better establish the effects on ECP of prior exposure history and plant-to-plant variations and how, in turn, the ECP value affects particle release rate and the likelihood of strand plugging.

EPRI Perspective

Previous work aimed at understanding the mechanism of strand plugging in water-cooled generators was performed in laboratory flow loops in which plant conditions were simulated. The current work was unique in that experiments were performed in sidestream flow loops attached to operating generators. Consequently, ECP and other relevant environmental and operating parameters monitored in this work were considered more representative of conditions that do, or could, occur in operating generators.

Keywords

Copper oxide
Corrosion
Electric generator strands
Electrochemical corrosion potential
Flow restrictions
Metal failure

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001014813

Generator Core Overheating Risk Assessment: Core Model Studies - 1009855

Product Type: Technical Report Date Published: 24-May-04

Abstract

Tests on a stator test model made from the Deely #1 generator correlated Electromagnetic Core Imperfection Detector (EL CID) and other data with a series of artificially induced shorts to evaluate existing acceptance criteria for test methods. Although additional work needs to be conducted, the present acceptance criteria for all test methods appear to be conservative and higher limits could probably be allowed, especially for shorts at the top of the teeth.

Background

This report follows up a previous study of San Antonio City Public Service Board's Deely #1 generator core (EPRI report 1008378). The Deely #1 generator was installed in 1976 and went into commercial operation in June of that year. The generator had major inspections with the rotor out approximately every five years with no major maintenance work. In February 1998 the stator was rewedged and the core tightness brought into conformance. In February 2001, after developing numerous shorts, the test stator was removed from Unit #1 after being classified unfit by several contractors who evaluated El CID and loop test data. The stator was turned over to EPRI as a test generator core in September 2002, and a study was initiated to determine the root cause of the high number of shorts in the Deely #1 generator core and to determine why it was able to operate when core test results were above recommended limits. Primary evidence gathering included visual inspections, EL CID, DIRIS, and loop tests and observations made on test samples following lab work. Because all the shorts indicated by the various test methods were found to be at the tooth tips, shorts at other locations could not be evaluated. It was decided to build a model of the stator core using laminations and other components from the Deely core in which faults could be introduced at various locations. It was also decided to develop a computer model that could assist in the evaluation of shorted laminations, especially those that are embedded and deep seated. It was theorized that by calibrating such a model from observations made during low and rated flux tests, the effect of that short could then be estimated during operation.

Objectives

- To correlate EL CID test patterns and signal levels with known faults in different locations of a stator core.
- To evaluate existing acceptance criteria for all test methods.

Approach

The project team used 55,000 lbs (22,700 kg) of stator iron from the Deely stator to construct a stator core model consisting of 9 packs of laminations separated by vents compressed between two plates via building bolts and through bolts. The team introduced a series of surface and embedded shorts and conducted EL CID, DIRIS, and rated flux tests to measure activity on the artificially introduced shorts. The team then used the Flux2D software package to implement a finite element analysis (FEA) of the stator model.

Results

The present acceptance criteria for all test methods appear to be conservative and higher limits could probably be allowed, at least for shorts at the top of teeth. Defects in the slot should be considered of particular concern. These are likely to be hotter than those on the tooth tops, since they are not cooled as well and the length of the current path is shorter. Finite element analysis modeling has the potential for better defining the severity of an indicated short and thereby helpful in establishing more accurate acceptance criteria.

EPRI Perspective

Until there is better information, the present acceptance criteria should remain in effect for defects that are in the slot or below. For those definitely at the tooth tops, the Deely experience would seem to indicate that the limit could be raised to at least 150 milliamperes for the EL CID. Additional tests should be made using the stator core model after the embedded shorts are improved.

EPRI addressed industry-wide issues of core maintenance and repair in EPRI report 1007441, "Repair and Testing Guide for Generator Laminated Cores Grounded at the Core Outside Diameter."

Keywords

Electric Generators
Electrical Faults
Finite Element Method
Magnetic Cores
Risk Assessment
Stators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001009855

Generator Core Overheating Risk Assessment: J. T. Deely Core Investigation - 1008378

Product Type: Technical Report Date Published: 24-Sep-03

Abstract

This report details an EPRI-sponsored study of San Antonio City Public Service Board's Deely #1 generator core. The Deely #1 generator was installed in 1976 and went into commercial operation in June of that year. The generator had major inspections with the rotor out approximately every five years with no major maintenance work. At one of these inspections in October 1992, the core tightness was evaluated and found to be above 90% of the original tightness; the wedging also was found to be tight. At the next inspection in February 1998, 80% of wedges were loose and core tightness was down to 45%. The stator was rewedged and the core tightness brought into conformance. Following this maintenance program, numerous shorts developed and continued to develop between laminations. In February 2001, the test stator was removed from Unit #1 after being classified unfit by several contractors who evaluated EL CID and loop test data. The stator was turned over to EPRI as a test generator core in September 2002.

Objectives

This study was initiated to determine the root cause of the high number of shorts in the Deely #1 generator core and to determine why it was able to operate when core test results were above recommended limits. A direct comparison to various types and effectiveness of core testing—with variations—also was explored. Industry-wide issues of core maintenance and repair were addressed with a deliverable document of procedures for core repair and testing (EPRI report 1007441, "Repair and Testing Guide for Generator Laminated Cores Grounded at the Core Outside Diameter").

Approach

The research team reviewed the history of prior core testing at Deely #1. It looked at the operating history for any triggering events or indicators before the time of outage. The team also looked for evidence in the core's maintenance history—in the tests and work performed—that would impact the fault area or lead to the fault. Primary evidence gathering included visual inspections, tests (EL CID, DIRIS, and loop), and observations made on test samples following lab work.

Results

Results of the Deely core tests:

- Electromagnetic Core Imperfection Detector (EL CID), DIRIS, and loop tests confirmed that the overwhelming location of shorted laminations was at the top of stator teeth. Only one of eighteen indications studied was deeper than the top of the tooth according to EL CID readings, but passed the 10-degree limit by loop test standards.
- When windings and wedges were removed, only slight changes were indicated by any of the test methods. There was no evidence that shorts were at the wedge groove area or that wedges contributed to hot spots.

- Shorted laminations were easily repairable with mica insertions after the winding was removed.
- Several laminations were artificially aged in hydrogen at temperatures up to 220 °C ; the properties of the Alkophos coating did not change.
- Lamination coating was highly uneven and entirely absent in many areas.

EPRI Perspective

For the Deely core, the only probable scenario for laminations to begin and continue to short out after tightening would be if the insulation was sparse in the initial state. This does not mean that a core replacement was required. In this case, the core did not reach damaging temperatures because tooth tips were well ventilated and there was a probable decrease in axial pressure in operation due to the differential between the through bolts and the core, which lowered shorting levels. The expense of core replacement should encourage efforts to repair core shorts with expert and experienced personnel—with a confident assessment of operation risks if shorts cannot be repaired.

Keywords

Electric Generators
Electrical Faults
Risk Assessment
Root-Cause
Stators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001008378

Generator Rotor Slot Dovetail Fretting Fatigue Cracks: Primer - 1009262

Product Type: Technical Report Date Published: 08-Dec-03

Abstract

Generator rotor slot dovetail fretting fatigue cracks have been found on the wedge land portion of rotor forging teeth for a number of different OEM (original equipment manufacturer) generator rotors in the past, and they are still being found today. The cracks have been associated with fretting of short steel wedges against the rotor forging in the slots. Pole face filler blocks made of steel also have caused fretting fatigue cracks in the axial stiffness-equalization slots in the pole faces of some rotors. This primer presents a 25-year history of the fretting fatigue problem.

Objectives

This document attempts to capture the basic history of the fretting fatigue problem and the general facts on how cracks initiate and grow, as well as repair alternatives. Also discussed are nondestructive evaluation (NDE) methods for detection and decision making when cracks are found.

Approach

The project team reviewed the history of fretting fatigue in generator rotors. They focused on how cracks initiated, grew, and how repairs, if any, were made. The team also addressed how to make informed decisions about inspecting the rotors.

Results

Fretting fatigue cracking does not present itself as OEM specific, but rather rotor design specific. In general, cracks are initiated by fretting of the steel wedges against the dovetail of the rotor slot. If the wrong combination of short steel components is found in a rotor with high enough bending stress, there is a possibility of fretting cracks initiating near the end of the floating steel component. Once initiated, crack growth is propagated by high-cycle fatigue, depending on the stress intensity factor, geometry, temperature, and operating cycles.

EPRI Perspective

The fretting fatigue found so far appears to be fairly widespread but manageable. Cracking has all been repairable to date with no forgings reported scrapped. During the past three years ending November 2003, approximately 30 generator rotors have been inspected in North America with nine of these units having cracks, linear indications, or fretting. Generally, cracks have been found in rotors when wedges were removed and slots inspected as part of a copper dusting inspection. Cracks have only been found in slots of 2-pole generators with short steel wedges present. Regardless of the actual configuration of slots and wedges, the ones to look at are those with short steel wedges.

Keywords

Crack Detection
Crack Initiation
Crack Propagation
Fatigue Cracking
Fretting Corrosion
Turbogenerators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001009262

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GENERATOR ROTOR RESEARCH

Generator Rotor Arcing: Theory and Simulation – 3002008541

Product Type: Technical Results Date Published: 10-Dec-16

Abstract

Retaining rings are an important and most highly stressed component of the generator. Arcing in retaining rings is a very serious problem and could easily escalate to a full–blown failure. In this project we simulate arcing in the retaining rings. We determine the most likely mechanism is a make-and-break contact arcing owing to the presence of inductance in the system and minute displacements of the ring caused by pulsating torque. This torque is a result of negative sequence rotor current interacting with the main magnetic field. Experiments to measure the contact resistance between the retaining ring and mild iron piece were needed for the computer simulation of the transients. Transient 3-D finite element simulations show that a make-and-break contact can generate localized voltage spikes, on account of a small contact break, which are high enough to lead to arcing.

Related Material

3002006238-Review of Damage to Generator Retaining Rings

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Arcing
Turbogenerators
Rotor
Retaining rings
Negative sequence currents

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008541

Review of Damage to Generator Retaining Rings - 3002006238

Product Type: Technical Report Date Published: 18-Dec-15

Abstract

This report reviews the inspection of the 172 generator rotors (344 retaining rings) and other rotor components from within Australia and New Zealand collected since 1995 as part of servicing generators. Inspections involved a combination of visual inspections and high sensitivity fluorescent dye inspections in conjunction with microscopic studies of the retaining rings. Available inspection data has been research to ascertain rotor data, operating conditions, and damage sustained by the rotor. The data has been sorted in an attempt to ascertain if there are variables that have a greater influence on observed damage. Main objective of the review was to investigate the higher recorded incidence of arc and other damage in Australasia as compared to other regions.

Keywords

Stress corrosion cracking (SCC)
Generator
Generator retaining rings
Generator retaining-ring inspection
Generator retaining-ring damage
Arc damage

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006238

Best Practices to Avoid Problems During Generator Rotor Rewind - 3002004969

Product Type: Technical Report Date Published: 13-Nov-15

Abstract

Rewinds of generator rotors are done to replace aging insulation systems and prevent shorted turns, but shorted turns are not unusual after rewinds and several other problems can be encountered as well, including rotor grounds, generator rotor thermal sensitivity, and component installation problems. This report, based on interviews with 16 customers/users, discusses the causes of these issues and common remedies used to resolve or avoid problems. Many issues can be addressed by choosing the right options for the specific rotor and creating and adhering to a detailed specification. Deciding when to rewind, whether to use new or existing copper, and what modifications of future cyclic duty will be necessary depend on several factors. A rewind in a facility that has a high-speed balance capability is the best option, but the risks of transportation and the added cost need to be evaluated on an individual basis.

Keywords

Generator rotors
Shorted turns
Rewinding rotors

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004969

Risk-Informed Inspection of 18Mn 18C Generator Retaining Rings - 3002003589

Product Type: Technical Report Date Published: 17-Nov-14

Abstract

Generator-rotor retaining rings, which rotate with the rotor and are typically made of nonmagnetic steel alloys, are the most highly stressed components in the entire turbine and generator-rotor system. Until the mid-1980s, an alloy containing 18% manganese and 5% chromium (18–5) was in worldwide use in generators. This alloy was susceptible to stress corrosion cracking (SCC) while operating in relatively mild environments, including exposure to moisture. In the mid-1980s, a new nonmagnetic alloy, containing 18% manganese and 18% chromium (18–18), was developed specifically to eliminate susceptibility to SCC damage. Since that time, retaining rings made of the 18–18 alloy have been successfully used in generators, with no known catastrophic failures and only rarely detected damage of any origin—including SCC. However, after 30 years of operating experience, some equipment manufacturers have now been recommending a comprehensive, time-based inspection program for all 18–18 rings in service. EPRI has therefore initiated a project to assess the operational history of the 18–18 alloy to determine if such an inspection program is justifiable and/or what levels of inspection and inspection approach would be appropriate and cost-effective. The primary objective of this project was to provide generator owner/operator recommendations regarding site-specific risks, based in part on responses to an industry-wide survey. No time-based generic issues for 18–18 retaining rings were found; all issues found resulted from specific events. The industry survey identified three event-driven damage mechanisms for 18–18 rings. The most prevalent mechanism is arcing damage between the ring and either the rotor or the amortisseur winding. Nearly half of the 10% of the total ring population that had some form of damage was attributed to arcing. The second damage mechanism is fretting, caused by relative motion between the retaining ring and the mating shrink-fit surface on the rotor. The stress source for fretting is frequent, high-load fluctuation leading to torsional oscillations. The third damage mechanism is stress corrosion and SCC. However, in contrast to the predecessor 18–5 alloy, the incidence for these types of damage for 18–18 alloy rings was very low (approximately 0.5%), and in all cases involved exposure to extremely aggressive environments not typically found in generators—specifically halogens (fluorine, chlorine, or bromine) and sulfur.

Keywords

Generator
Generator retaining rings
Generator retaining-ring inspection
Generator retaining-ring damage

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003589

Generator Fan/Blower Design, Inspection, and Maintenance - 1025335

Product Type: Technical Report Date Published: 13-Dec-12

Abstract

Turbo-generator rotor cooling fans and blowers are highly stressed components of a generator rotor. As such, their failures can result in expensive damages and extended outages. This best practices document provides guidelines that help plant managers understand potential failure mechanisms and their root causes, anticipate issues before failures occur, and prepare inspection and contingency plans.

The guidelines are applicable to both nuclear and fossil turbo-generator rotors. Both axial and radial cooling fan/blower design variations and material choices are reviewed. Potential failure mechanisms are explained and root causes identified. Case studies document industry experience with maintaining cooling fans/blowers and securing balance weights and radial terminal studs. Best practices for disassembly and reassembly of components, inspection techniques, repair methods, and maintenance planning are summarized. Design review questions are provided to assist plant engineers when procuring new equipment or major repair service.

Keywords

Blowers
Fans
Generator Rotors
Securing Balance Weights
Turbo-Generator Best Practices

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001025335

Main Generator Rotor Maintenance - 1013458

Product Type: Technical Report Date Published: 27-Nov-06

Abstract

Main generator rotors are constructed and designed to provide decades of reliable and trouble-free operation. However, a number of incidences have occurred over the years that can adversely impact reliable operation of generator rotors and, ultimately, production of electrical power. This report is a guide for power plant personnel responsible for reliable operation and maintenance of main generators. As a guide, this report provides knowledge and experience from generator experts working at power plants, utility companies, and generator service vendors. The report is not intended to provide detailed instructions for generator rotor maintenance; rather, it offers the experience, lessons learned, and best practices from others who have knowledge and expertise maintaining generator rotors.

Objectives

This project provides power plant utilities with a guide based on experiences of other plants in performing rotor maintenance, dealing with significant rotor issues and problems, and rotor refurbishment. In particular, generator system engineers, maintenance engineers and managers, and others directly involved with maintaining and upgrading generator rotor systems will benefit from the report.

Approach

The project team developed this report using input from utility personnel with experience maintaining and operating power plant main generators. Survey forms were used to collect basic information on generator rotor maintenance. Responses were received from utilities on 118 generators. The team held discussions with a number of survey respondents to collect further information. Additional information was gathered from generator service vendors and industry literature, including EPRI reports. A number of utility experts reviewed and commented on the draft of this report; their comments and recommendation have been incorporated into the final version.

Results

Forty-seven best practices and twenty-seven lessons learned from utilities and vendor service providers who have experienced and dealt with rotor issues are included in the report's appendices. The body of this report builds on the best practices and lessons learned with additional information provided by utilities and manufacturers to guide power plant personnel in the maintenance, operation, and possible upgrade of their main generator rotors.

Application, Value, and Use

A number of power plants have successfully implemented rotor repairs and refurbishments and have dealt with identifying and correcting rotor problems having the potential of becoming major reliability issues. The experience and knowledge gained by these plants' personnel serve as valuable resources that should be made readily available to benefit the entire electric utility industry. Additionally, equipment manufacturers, service providers, and other vendors have amassed a wealth of information on maintaining, refurbishing, and upgrading generator rotors that also will be valuable to the electric utility industry.

This report makes the knowledge and experience of these plants and vendors readily available. Lessons learned, best practices, and other information collected from power plants and vendors have been used as a means to help others maintain, refurbish, and upgrade their generator rotors.

EPRI Perspective

Providing the experience, lessons learned, and best practices from power plant personnel offers unique insight into generator rotor maintenance. Building on input from utility personnel, this report offers readers an overview of practices and techniques performed by their peers at other power plants.

Keywords

Best Practices
Lessons Learned
Maintenance
Rotor

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013458

Optimized Maintenance of Generator Rotors - 1004951

Product Type: Technical Report Date Published: 13-Dec-04

Abstract

Generator rotor maintenance options are limited and expensive. The timing and scope of work done requires optimization to obtain the maximum benefits for continued long-term trouble-free operation. This document is a comprehensive guide to the maintenance of large generator rotors of 2 and 4 pole design that are cooled directly or indirectly by air or hydrogen. These include 50 and 60 Hz machines, operating at speeds of 1500, 1800, 3000, and 3600 RPM. The guide does not cover water-cooled rotors. The information included in the guide is generic in type, covering all the major generator manufacturers worldwide.

Objectives

Operated on base load, many generator rotors can provide a trouble-free service life of 25 years or more. However, deregulation in the power industry has forced some generators away from base load operation; the resulting increased thermal and mechanical cyclic duty has significant consequences for rotating equipment. Shifting and load following subject rotor forging teeth, wedges, copper windings, and connectors to low and high cycle fatigue mechanisms and insulation materials to shear and thermal stresses. At the same time, previously known phenomena such as stress corrosion cracking of retaining rings and torsional resonances, excited by grid transients, have a major impact on rotor design and choice of materials.

Approach

The project team compiled the information in the guide from numerous sources of available data, including equipment vendors, EPRI, the IEEE, and the International Council on Large Electric Systems (CIGRE).

Results

The Guide provides:

- Information on rotor basics and design issues
- A description of the major components of the rotor and their purpose
- A discussion of the known rotor problems, how they manifest themselves, and how they can be corrected
- A discussion on rotor shorted turns and ground faults
- A compilation of on-line monitoring and diagnostic methods
- A compilation of off-line test methods
- A discussion of various maintenance practices
- A discussion on rotor inspection and maintenance items

EPRI Perspective

As a focus of innovative approaches and techniques, maintenance of aging steam turbines has assumed increased importance. Many old steam plants, particularly those that are coal fired and well maintained, can be positioned to succeed in the current deregulated environment. To support this goal, EPRI is developing a series of engineering guidelines, repair procedures, and support technologies. This report is part of that effort.

Keywords

Maintenance
Optimization
Rotors
Turbogenerators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001004951

9

EXCITER, ISOPHASE BUS, AND BUSHINGS RESEARCH

Turbine-Generator Topics for Power Plant Engineers: Synchronous Generator Voltage Regulator Basics - 1024804

Product Type: Technical Update Date Published: 16-Feb-12

Abstract

This material is intended for the new engineer, the control room operator, management, or the non-engineer. The basics of a synchronous generator excitation system; the fundamentals of the voltage regulator; and its controls and functions are discussed. The typical exciter types are covered, but not in detail. There is also basic information on voltage regulator maintenance issues.

Put simply, the excitation system is made up of three basic component systems. The voltage regulator monitors the synchronous generator's output terminal voltage and current and sends control signals to the exciter. The exciter then controls the synchronous generator field current to maintain the desired generator terminal voltage and thus the requirements of the "system." The Federal Energy Regulatory Commission formally calls the system the bulk electric system. Both terms are used here. The variety of voltage regulators and their features are legion, but their functionalities are quite similar.

Keywords

Excitation System
Exciter
Synchronous generator
Voltage regulator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001024804

Generator Bushing Installation and Maintenance Guide - 1016787

Product Type: Technical Report Date Published: 04-Dec-08

Abstract

This report is a comprehensive guide to generator high-voltage bushing (HVB) installation and maintenance.

Background

EPRI's Steam-Turbine, Generator, and Balance-of-Plant program addresses the need for plant operators to manage unit operation, maintenance, and performance cost-effectively through independent analysis and testing methods. The program develops technology, applications, and guidelines that help plant operators achieve reductions in forced outage rates, shorter scheduled maintenance outages, and improved steam turbine performance. This guide provides nuclear and fossil power plant personnel with maintenance guidelines for shipment, storage, removal, and re-installation of HVBs for all types of utility generators.

Objectives

- To discuss specifics of current and past practices as they relate to HVB installation and maintenance recommendations.

Approach

The author details all major aspects of generator HVB installation and maintenance, from shipping and storage prior to installation to HBV removal and site preparation for installation. HVB installation designs are considered along with gasket and bolt selection. The author also provides a simple torque calculation for designing an HVB / gasket interface, addresses installation concerns (including pre- and post-testing), and recommends HVB inspection intervals.

Results

- The report focuses on these key areas of generator HVB:
- Site preparation prior to removal / installation
- Gasket and bolting selection
- Geometries of flange / porcelain interface
- Torque calculation
- Testing
- Failure history and failure modes
- Inspection intervals

EPRI Perspective

HVB failure causes are widespread and affect many HVB manufacturers. In some cases, repairs can be performed and HVBs put back in service. In other cases, HVBs should be replaced because long-term repairs are unavailable. Each case must be evaluated separately with utility owners actively involved in vendor repair options, from shipping of new units to installation and scheduled maintenance. This guide will assist utility owners will all aspects of HVB installation, repair, and maintenance.

Keywords

Electrical generator
High-voltage bushings
Maintenance
Terminals

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001016787

Nuclear Maintenance Applications Center: Isolated Phase Bus Maintenance Guide - 1015057

Product Type: Technical Report Date Published: 20-Dec-07

Abstract

This report provides information on design, operating experience, and maintenance practices associated with the isophase bus system. The information is meant to be useful for system engineers, component engineers, maintenance personnel, and their supervision in understanding and maintaining this system. This document is an update to Isolated Phase Bus Maintenance Guide (EPRI report TR-112784), and the scope has been expanded to include boundary components, such as potential transformers (PTs) and current transformers (CTs) that also affect system reliability. The Institute of Nuclear Power Operations (INPO) operating experiences that have occurred since the original report's release were gathered, analyzed, and evaluated to provide insights into recommended maintenance practices. Additionally, a table of maintenance tasks and frequencies has been provided for guidance in maintaining system reliability.

Objectives

This report should be useful to system/component engineers who are unfamiliar with the design of the isophase bus system and the operating experiences that have impacted system reliability. This document is also useful to system engineers in evaluating the correct predictive and preventive maintenance activities for the system. Maintenance personnel should find the insights on improved and proper bolting techniques of electrical connections useful in reducing occurrences of high-resistance connections and repeat maintenance of them. The document also provides insight to system/component engineers and maintenance personnel in troubleshooting this system.

Approach

The initial research was based on member feedback for improvements to the original document. A tremendous resource was a thorough review of industry operating experience and technical advisory group member experiences since the original report was written. Other material was gathered from existing EPRI research on maintenance task and frequencies that was not available when the original report was issued. Finally, input from the original author and an industry consultant was incorporated to provide additional insight specifically on improving bolted connections. The scope was expanded from the original document, which included the electrical bus, the bus duct cooling system, and monitoring, to include CTs, PTs, neutral bus, and miscellaneous subcomponents.

Results

The isophase bus system continues to be a frequent contributor to industry operating experience. In addition, many components of the system are susceptible to age-related degradation or deterioration due to frequent manipulation, such as frequent removal of bus links for system isolation. This update is meant to provide additional guidance on system maintenance and testing to increase and extend system reliability through plant life extension.

Application, Value, and Use

This document has been updated to improve the usefulness in determining the correct maintenance tasks based on insights from operating experience over the last 10 years. Additionally, maintenance personnel should benefit from insights provided on key inspections, inspection methodology, visual images of the component deterioration, and methods to improve the integrity/ease of installation/removal of large electrical bolted connections.

EPRI Perspective

This report expands on the original guidance provided in TR-112784. Specifically, it provides maintenance tasks for many of the subcomponents of the isophase bus system as well as some ideas on improvements in the many bolted connections that have been problematic. The guide is meant to be a comprehensive source of historical design information, recommended maintenance tasks, and maintenance practices.

Keywords

Electrical equipment
Isophase bus
Non-segregated bus
Segregated bus
Turbogenerators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001015057

Main Generator Excitation System Upgrade/Retrofit - 1011675

Product Type: Technical Report Date Published: 07-Nov-05

Abstract

Upgrading or replacing even a portion of the excitation system of a generator can provide increased reliability and availability while simultaneously decreasing operational and maintenance costs. However, the upgrade or retrofit of an excitation system is a major cost involving some degree of implementation, installation, or performance risk. This report provides lessons learned, experiences, practices and solutions from plants that have installed excitation system retrofits and upgrades. This information will help electric utilities:

- Maximize their benefit-to-cost ratio by improving installation efficiency
- Help reduce possible difficulties and risks associated with the installation and operation of an upgrade or retrofit
- Ensure the best possible implementation and installation of upgrade/retrofit

Objectives

This project is intended to provide power plant utilities with a guide to performing excitation system modifications based on the experiences of other plants. A number of power plants have successfully implemented excitation system upgrades and retrofits. The experience and knowledge gained by personnel at these plants is a valuable resource for the entire electric utility industry. Equipment manufacturers, service providers, and other vendors have also amassed a wealth of information on performing excitation system modifications that will be valuable to the electric utility industry. This project and report makes the knowledge and experience of these plants and vendors readily available. In particular, excitation system engineers, design engineers, project managers and others directly involved with upgrading and retrofitting an excitation system will benefit from the "Lessons Learned," "Best Practices," and other information in this report.

Approach

The project team gathered information from power plants that have already completed an excitation system upgrade or retrofit. Ninety-one power plant units provided input through an initial e-mail survey. From the ninety-one units that responded to the initial survey, the team selected twenty-one companies that had reported extensive experience with excitation system modification to provide more detailed information. The team interviewed several of the companies that had the most experience to gain the maximum amount of their experience. The team also performed a literature search of standards, reports, and papers regarding excitation upgrades or retrofits and obtained further information from excitation system equipment manufacturers and service providers. Five manufacturers and service providers agreed to be interviewed and provide information from their vast experiences with excitation system upgrades and retrofits. A committee of representatives of seven utilities experienced with excitation upgrades and retrofits contributed their time and effort by reviewing the draft of this report and progress of the project. The review committee provided beneficial recommendations and additional information that are incorporated in this report.

Results

The appendices of this report provide forty-five "Best Practices" and twenty-nine "Lessons Learned" from utilities that have performed excitation system upgrades and retrofits. The body of this report builds upon these "Best Practices" and "Lessons Learned" with additional information provided by utilities and manufacturers to guide power plants in the upgrade or retrofit of their excitation systems.

Application, Value, and Use

This report serves to provide guidance in the upgrade and retrofit of main generator excitation systems. It will be beneficial to any utility considering implementing an excitation system modification. As equipment improves and changes with time, this report will remain a valuable tool. The guidance provided by this report and the "Lessons Learned" and "Best Practices" submitted by experienced plants will remain valid regardless of the excitation equipment involved in a modification.

EPRI Perspective

Previously published EPRI report 1004556 Tools to Optimize Maintenance of Generator Excitation System, Voltage Regulator, and Field Ground Detection discusses excitation system maintenance. This report and the project which produced it provides "Best Practices," "Lessons Learned," and additional information based upon the experience of power plants that are experienced with excitation systems upgrades and retrofits. Additionally, manufacturers and other vendors experienced with providing excitation equipment and services provided input into this report. A review committee of experienced personnel from seven utilities reviewed the report to ensure that this report will provide appropriate guidance to other utilities considering and implementing their own excitation system upgrade or retrofit.

Keywords

Best Practices
Excitation System
Lessons Learned
Main Exciter
Main Generator
Retrofit
Upgrade
Voltage regulator

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001011675

Tools to Optimize Maintenance of Generator-Excitation System, Voltage Regulator, and Field Ground Protection - 1004556

Product Type: Technical Report Date Published: 04-Dec-02

Abstract

This report contains information to optimize maintenance of generator-excitation systems, voltage regulators, and field ground protection.

Background

Main generator excitation system failure, though not occurring frequently, can cause a high value of loss. The cost of lost generation can greatly exceed the cost to repair the excitation system. The advent of new maintenance and diagnostic technologies and techniques has greatly reduced the cost of maintaining the excitation system in a high state of reliability. With the fiscal restraints many power plants now have on their operating and maintenance budgets, a program of a low cost-benefit ratio is needed to maintain and improve reliability and availability.

Objectives

- To determine commonly performed excitation system maintenance tasks used by generation plants, to identify excitation system failures occurring in generation plants, to identify component failure rates per make and model of excitation system, and to determine the most effective maintenance tasks and programs for excitation systems.

Approach

The project team surveyed generation plants for excitation system maintenance and failure data. The team also reviewed industry databases for excitation system failure data. Team members compiled and analyzed data for common failure and maintenance practices. They researched industry literature, including IEEE standards, and manufacturer documents. From the data analysis and literature review, the team developed an effective maintenance program.

Results

Excitation systems vary greatly in the type of equipment and the method of producing generator excitation. The maintenance performed by power plants on the excitation also varies greatly, even when plants have the same type of excitation system. However, there is some commonality among the diverse systems. For example, almost all types of excitation systems use brushes to apply excitation current to the generator's rotating field. Brushes are one of the components requiring the most labor to ensure reliable performance. Furthermore, brushes and associated components are involved in a disproportionate number of personnel safety issues due to the electrical shock hazard they present.

Predictive maintenance (PdM) technologies and techniques provide opportunity for enhancing reliability while reducing the need for certain preventive maintenance (PM) tasks. Although many PM tasks remain necessary for reliable system operation, reducing the number and possibly the frequency of PM tasks with PdM technologies increases the availability of the system and decreases maintenance costs. Maintenance tasks, including both PdM and PM tasks, are described in this report. A typical routine maintenance plan also is given.

Cost-benefit analysis provides a tool to determine the appropriate tasks and frequencies of maintenance. Using cost-benefit analysis, a plant can develop a maintenance plan that provides a cost-effective balance of system reliability and maintenance tasks. Cost-benefit analysis can be used to determine whether excitation system components should be replaced, upgraded, or maintained for optimal cost-effectiveness. The report provides a detailed description of a cost-benefit analysis.

The information in this report will help plants benefit economically by using appropriate levels of PdM and PM tasks; older plants can benefit as well, possibly through equipment upgrades.

EPRI Perspective

This project provides users with a tool to assess their excitation systems for failure probability and to take appropriate actions to monitor and rectify potential problems prior to failure. Maintenance failure data and analyses will assist users with condition monitoring and maintenance optimization of their excitation systems. This maintenance guide provides a detailed overview of the excitation system and components, failure mechanisms, appropriate maintenance diagnostic and monitoring practices, and recommendations for increasing reliability and efficient maintenance.

Keywords

Brushes
Cost Benefit Analysis
Electromagnetic Fields
Maintenance
Voltage Regulators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001004556

10
TURBINE GENERATOR BEARINGS AND LUBRICATION

Bearing Action Advisor (BAA) Version 1.0 - 3002003908

Abstract

The EPRI Bearing Action Advisor (BAA) 1.0 software product is intended to provide a bearing damage assessment application that, based on user-supplied observations about bearing condition and individual risk tolerance, provides run vs. repair/replace decision-making guidance for utility personnel. The BAA 1.0 release is focused on two bearing types: cylindrical horizontal and bumper thrust.

To view this application please go to http://bearingaction.epri.com

Benefits and Value

Allow users to determine the recommended course of action in regards to bearing damage

Allow users to access application on a variety of mobile devices

Will include offline data storage so that certain bearing damage assessment inputs can be collected without an active internet connection

Platform Requirements

The default web server will be Windows 2008 R2 Server.

- The default back-end database will be Microsoft SQL Server 2008 R2.
- The following browsers will be supported:
  - Internet Explorer 9.0 and higher
  - Firefox 10.x and higher
  - Chrome – Most current version

Keywords

Bearing damage
Bearing Action Advisor
Bearing condition
Risk tolerance
Cylindrical Horizontal
Bumper Thrust

Remediation of Lost Demulsibility in Turbine Oil- 3002005576

Product Type: Technical Report Date Published: 15-Jul-15

Abstract

Proper lubrication of plant components is critical to reliable operation. For steam turbines, the oil used must be maintained within acceptable parameters to prevent component wear, premature replacement of lube oil, and possibly catastrophic damage to the turbine generator system. Several major original equipment manufacturers (OEMs) produce a variety of lubricating oils, and all of these have characteristics in common as well as key differences that may change their behavior in service. One characteristic is demulsibility, the ability of lube oil to easily separate from water, which allows water removal equipment to function efficiently and prevent problems associated with high water content. This report focuses on the EPRI investigation into one potential technique for remediation of failed demulsibility.

Background

In 2014, an EPRI member using Group II base stock oil in multiple combined-cycle steam turbine applications found reduced demulsibility during routine oil monitoring. Common causes of failed demulsibility were believed to be ruled out, the most common being contamination with detergents. Two plants were affected, and based on oil OEM suggestions, both purchased approximately 14,000 gallons of new turbine oil of the same brand that had failed. Within six months, both plants again had failed demulsibility.

Oil demulsibility is critical for steam and hydro turbines, as both are designed with opportunities for water to ingress into the oil. If the turbine oil does not separate readily from water, catastrophic bearing damage, bacterial growth, and component wear may occur. Also, some water removal technologies, such as coalescers, are less effective if the turbine oil has poor demulsibility characteristics, providing the plant with an artificial sense of security.

The EPRI member company sought engagement from EPRI on this issue, and during a literature search and collaboration with other industry experts it was noted that this may be a widespread issue with Group II base stocks. EPRI began an investigation into how this issue may be rectified, and settled on testing one hypothesis supported by plant case studies, namely, that sweetening Group II lube oils with Group I oil may restore demulsibility of degraded Group II oil.

Objectives

EPRI pursued a series of laboratory tests on mixtures of degraded Group II lube oil and new Group I lube oils to test the hypothesis that these mixtures may allow failed Group II oils to pass the ASTM D1401 water separability test.

Approach

The investigation began by contacting plants that had a known demulsibility issue with Group II oil and that had sweetened with a Group I oil as part of a program to restore the lube oil system to recommended specifications. Through these case studies, data was collected on the severity of the plant issue, the corrective actions taken, and the long-term results. These case studies supported the initial hypothesis, and samples of degraded Group II and two brands of Group I were sourced and sent to an oil analysis lab for compatibility and demulsibility testing in various mixtures.

Results

Lab results showed that the two brands of Group I oil sourced, Monolec 6461 and XPG 32, are compatible, by ASTM D7155, with the degraded Group II oil, GST 32, and that as little as 5% Group I mixed with degraded Group II has a significant impact on demulsibility results.

Applications, Value, and Use

For plant staff using Group II turbine oils and finding degraded demulsibility, these test results show one potential approach to dealing with the issue without incurring the cost of disposing of and resourcing a full charge of lube oil.

Keywords

Demulsibility testing
Group I base oil
Group II base oil
Oil compatibility
Turbine lube oil
Turbine lubrication

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005576

Backup Oil System Maintenance Guide - 3002003593

Product Type: Technical Report Date Published: 24-Nov-14

Abstract

Several recent failures have occurred in which the main turbine has coasted to zero speed without oil to one or more bearings. This condition causes severe damage to the bearings, journals, and steam path components, requiring significant amounts of time and money to repair. Escape of hydrogen from the generator, with subsequent fire and personnel and equipment risk, can also occur. There are several backup systems in place to prevent this condition that are meant to ensure that when main oil pressure is lost, oil is still delivered to the bearings and hydrogen seals. This report builds on existing guidance contained in past Electric Power Research Institute (EPRI) reports and other relevant sources to develop a comprehensive document covering maintenance and testing of backup oil systems for nuclear, fossil, and combined-cycle applications.

Program

2014 Program 65
Steam Turbines-Generators and Auxiliary Systems

Keywords

Backup oil systems
Bearings
Hydrogen

Oil

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003593

Field Guide: Bearing Damage Mechanisms - 1026566

Product Type: Technical Report Date Published: 06-Nov-12

Abstract

Electric Power Research Institute (EPRI) report 1021780, Manual of Bearing Failures and Repair in Power Plant Rotating Equipment, 2011 Update, is a comprehensive document on the subject of fluid film bearing damage modes. This field guide provides a pocket reference based upon the content of that report.

Background

EPRI is pursuing a series of field manual style projects that seek to reformat EPRI and industry knowledge into a more user-friendly format. This guide is designed to be portable and includes information useful for personnel seeking to identify failures in the field. By creating guides in a more portable format that are graphics-intensive, while retaining references to more in-depth sources, EPRI believes that the research done by the Institute will be made more available and useful to plant staff.

Objectives

Following a correct identification of the mode of failure for a bearing, the next logical step is to determine the root cause. This is undoubtedly the most challenging part of an investigation. Although the path from failure symptoms to an identification of the mode of failure is more or less direct, a number of different causes may have provided the necessary conditions for initiating the damage mechanism. Considerable supplementary information is usually needed, including equipment records, running conditions, past and present experience, and other circumstantial evidence, before the specific cause of failure can be isolated.

This field guide presents a number possible causes for each damage mode and juxtaposes these with suggested remedial actions. The list of causes and remedies is not necessarily exhaustive, but will provide some initial leads in the investigation.

Approach

This field guide was developed from the content of EPRI report 1021780, Manual of Bearing Failures and Repair in Power Plant Rotating Equipment: 2011 Update.

Results

Fluid film bearings of the type used in power plant equipment are susceptible to more than a dozen categories of bearing damage. These can lead to substantial outages and costly repairs. Recognizing the damage mechanism responsible for a given failure and associating it with a root cause is a key step in avoiding future incidents. Visual inspection, combined with an understanding of specific plant conditions, can usually provide the necessary clues to diagnose the problem.

Application, Value, and Use

This field guide provides the plant engineer and other personnel with guidance in determining the origin of a given bearing failure and indicates how best to address the contributing causes.

Keywords

Bearing damage
Bearing refurbishment
Bearing repair Bearings
Turbine generator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001026566

Reference Poster: Turbine Bearing Damage Mechanisms - 1026557

Product Type: Technical Update   Date Published: 04-Oct-12

Abstract

Damage to turbine and generator bearings accounts for a significant amount of lost generation in the power industry. There are numerous known damage mechanisms affecting these bearings, and as part of EPRI's technology transfer efforts, we have developed a reference poster. This poster provides clear, concise, and visual information for a wide variety of mechanisms and is meant to supplement related EPRI projects. By providing an overview of various issues as well as information on how to mitigate and repair turbine and generator bearings, power generators can improve reliability and availability of their machines

Keywords

Journal bearing
Poster
Thrust bearing
Turbine-generator bearings

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001026557

Manual of Bearing Failures and Repair in Power Plant Rotating Equipment - 1021780

Product Type: Technical Report Date Published: 15-Dec-11

Abstract

Turbine bearing failures in electric utilities can be responsible for outages resulting in significant lost generation time. In addition to bearing failures in the turbogenerators, failures may occur in other rotating equipment, such as pumps, fans, and auxiliary systems. Knowledge of bearing failure mechanisms and causes allows utilities to introduce safeguards into their occurrence and take faster remedial action.

EPRI released the initial report, Manual of Bearing Failures and Repair in Power Plant Rotating Equipment (GS-7352), in 1991. For 2011, EPRI has updated this report with applicable operating experience from the past 20 years and has reorganized the document to aid in the quick access of valuable information. The goal of this report is to provide the industry with a comprehensive encyclopedia on the subject of bearing failure and cause diagnosis.

Keywords

Bearing damage
Bearing refurbishment
Bearing repair
Bearings
Turbine generator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021780

Nuclear Maintenance Applications Center: Turbine Oil Compatibility - 1016272

Product Type: Technical Update Date Published: 26-Mar-08

Abstract

As oil companies continue to consolidate product lines, utilities are faced with oil formulation changes. These new generation oils contain updated additive packages and more highly refined base stocks, which raise concerns over performance and oil compatibility within existing systems. Moreover, the reformulated oils may not perform as expected when mixed with traditional in-service oils or may not perform as expected in some machines. Prior experiences with foaming and deposit issues seem to have been linked to base oil and additive changes. The purpose of this project was to conduct rigorous lab testing in order to evaluate stated performance levels of Mobil DTE 732 turbine oil and its compatibility with in-service lubricants, Mobil DTE 797 and Exxon Teresstic GT 32.

Objectives

Procurement engineers, lubrication engineers, and maintenance personnel need to feel confident in the use of reformulated turbine oil that is replacing discontinued turbine oils. The objective of the testing and reporting was to independently evaluate the claims of ExxonMobil with regard to the DTE 732 product and to support plant personnel in the purchase and use of the product. EPRI has coordinated and funded this effort in order to save the industry substantial amounts of money and time. In particular, EPRI clients will save lubricant test costs and needless delays in analysis. Further savings will accrue in the confidence that these lubricants are compatible and that total changeout of the in-service lubricant is not required. Additions of the new product are acceptable if the existing oil is within specifications.

Approach

The goal of the study was to demonstrate that a new formulation turbine oil, Mobil DTE 732, would be suitable for use in nuclear power plants, including its application as an incremental addition to the most common existing turbine oils (DTE 797 and Teresstic GT 32). To accomplish this goal, several tests were performed under EPRI's 10 CFR 50, Appendix B quality assurance program to evaluate the compatibility of various mixtures of new (reformulated) oil and used (traditional/in-service) oil. Five oil aliquots were tested for DTE 732 against new and used DTE 797 and Teresstic GT 32, including the following mixtures:

- 100% new DTE 732
- 90% new DTE 732/10% in-service oil
- 50% new DTE 732/50% in-service oil
- 10% new DTE 732/90% in-service oil
- 100% in-service oil

Results

Laboratory tests show that Mobil DTE 732 turbine oil performs as well or better than Mobil DTE 797 or Exxon Teresstic GT 32 and is compatible with either one should combinations occur. Current DTE 797 and Teresstic GT 32 users can be confident in the replacement or addition of DTE 732 to either of these products. Based on the laboratory testing, the use or addition of DTE

732 should yield superior performance and allow extended service life. This report does not characterize the effects of a loss-of-coolant accident (LOCA) or the lubricant's radiation resistance.

Application, Value, and Use

More reformulated turbine oils with new additive systems will be forthcoming in the lubricant industry. Other lubricant types will also contain the new hydrocracked base oils as more plants convert to modern production processes. Many plants use the same type of lubricant in feed pumps, coolant pumps, spray pumps, and other pump systems as they do in the main turbine system. The applications of these lubricants also range from safety to non-safety-related machines. Based on laboratory performance levels, the DTE 732 is equal to or better than either of the subject lubricants and can be mixed in any ratio. The data further indicate that there is an opportunity for increased service life using the new DTE 732.

EPRI Perspective

EPRI has the capability of verifying product manufacturer performance claims by independent laboratory testing and can arrange custom compatibility testing with products currently in service. Individual plants could sponsor these tests as well, but it is much more efficient to run such tests once—generically for all EPRI Nuclear Maintenance Applications Center (NMAC), Nuclear Steam Turbine Generator Initiative (NSTI), and Program 65 members—backed by unique EPRI expertise.

Keywords

Compatibility
Exxon Teresstic GT 32
Mobil DTE 732
Mobil DTE 797
Turbine oil

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001016272

11
TURBINE VALVES, ACTUATORS, AND CONTROL SYSTEMS

Evaluation of Condition Monitoring Methods for Steam Turbine Valves: Phase 2 – Sensors and Data – 3002008457

Product Type: Technical Results Date Published: 20-Dec-16

Abstract

As power plant asset owners continue to reduce maintenance spending, there is pressure to increase steam turbine valve overhaul intervals. Due to the critical role these valves play in regulating power and preventing turbine overspeed events, a conservative approach to maintenance has been taken in the past. As technology for equipment monitoring continues to improve in capability and deployed cost, there are opportunities to application to critical components that are potentially over-maintained.

This is the second in a series of reports that document the conceptual development of a turbine steam valve monitoring system. The project takes a comprehensive approach, starting with a failure modes effect analysis (FMEA) to identify currently un-monitored degradation. Sensor and data reduction options were then evaluated against the FMEA results and ranked. The result is a technical basis for the next phase of research that will involve controlled experimentation with damaged valve mockups.

This report provides useful information on potential future valve sensor options, sensor powering choices, signal and data processing options using compact decentralized hardware. Also covered are technical issues related to integrating these data into centralized monitoring and diagnostic centers.

Related Material

3002006235 Evaluation of Condition Monitoring Methods for Steam Turbine Valves: Phase 1-Failure Modes and Effects Analysis

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Valves
Condition monitoring
Health monitoring
Steam turbines

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008457

Evaluation of Condition Monitoring Methods for Steam Turbine Valves: Phase 1-Failure Modes and Effects Analysis - 3002006235

Product Type: Technical Report Date Published: 21-Dec-15

Abstract

This report describes a failure modes and effects assessment of hydraulically actuated steam valves that are used to control and isolate the steam supply to turbines used in commercial power generation. This work is part of a research project to identify and develop new methods for condition monitoring of steam turbine valves. The failure modes and effects assessment is the first step in a multiyear effort that seeks to improve the ability of plant operators to observe early degradation in valve condition. Subsequent work on potential monitoring and diagnostic technology will build on the results of this analysis.

Background

Hydraulically actuated valves used in steam turbine applications are key to protecting against turbine overspeed events. These valves are also used for maintaining unit output in accordance with system demand. It is, therefore, necessary to test these valves frequently and perform preventive maintenance at fixed intervals to ensure reliability. As plant operating and maintenance budgets are increasingly tightened and inspection intervals stretched, a need exists to explore how technology could be applied to improve valve condition monitoring. Improved monitoring could be the basis for a transition from a time-based to condition-based valve maintenance philosophy. If this switch could be made and could justify longer valve maintenance intervals with no increase in the risk of valve malfunction, plants could save considerable future maintenance costs.

Objectives

The objective of the research reported in this document is to conduct a formal failure modes and effects analysis on typical control and stop valve configurations used on steam turbine applications. The focus is on identifying where it may be possible to detect component degradation earlier, using either improved online or offline testing without requiring valve disassembly.

Approach

The research focused on common stop and control valve configurations manufactured by General Electric and Westinghouse (now Siemens). A risk priority number (RPN) was developed as a framework to assess the probability, consequence, and detectability of 22 common steam valve and associated actuator degradation modes. Relatively high RPN values indicate modes that could benefit from improved detectability, potentially offered by future advancements in valve condition monitoring. Following calculation of RPN data, the attributes of several condition monitoring options were explored in terms of their potential to reduce RPN. These options included offline diagnostic testing of the type currently used on air-operated valves and the improved use of control signal and valve stem position data.

Results

The failure modes and effects analysis indicated that nine degraded conditions associated with significant values of RPN can be lowered through the use of offline testing or online monitoring as described in the report. Most effective is the use of offline diagnostics and online valve control signal data. The major condition degradation issues that remain unaddressed by these proposed methods are sudden failures of linkages, springs, bolts, or spring cans, all of which do not typically reveal any signs of distress preceding failure.

Applications, Value, and Use

This report will inform future work at the Electric Power Research Institute (EPRI) on the development and field demonstration of new methods for steam valve condition assessment. Using the findings on potential risk mitigation, combined with the attributes of current sensor and data analysis systems, EPRI will provide specific industry recommendations in the next phase of this research. Plant operators can use the information in this report now to gain an improved understanding of relative risk associated with unmonitored condition degradation.

Keywords

Turbine valves
Valve diagnostics
Control valves
Actuators
Stop valves

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006235

Electrohydraulic Control (EHC) Fluid Maintenance Guide - 3002003594

Product Type: Technical Report   Date Published: 22-Dec-14

Abstract

The *Electrohydraulic Control (EHC) Fluid Maintenance Guide* provides plant personnel with information on the operation, maintenance, and performance of the electrohydraulic control (EHC) fluid system. The contents of this guide will aid plant workers in improving the EHC fluid system reliability, performance, and plant maintenance practices.

Background

EHC systems are used primarily on large nuclear and fossil steam turbines. The power industry has experienced problems with maintaining EHC fluid, which is contained in these systems, in good condition. Improper or inadequate fluid system maintenance has resulted in component failures and unit trips.

Objectives

- To assist with determining the causes and solutions for EHC hydraulic fluid-related component failures and trips
- To help implement these solutions to reduce unit downtime due to EHC fluid issues and increase the reliability of the entire system
- To provide detailed instructions for removing residue from the EHC system and specify the fluid maintenance procedures and processes that are required to prevent it from reoccurring in the system

Approach

The guide is focused on EHC fluid problems and solutions. Other EPRI guides have been referenced to give plant personnel a working knowledge of EHC pumping systems. Information has been gathered on troubleshooting for specific problems. A survey was conducted to gather data on the fluid maintenance practices that are occurring in the industry; the results were reviewed to identify parameters for fluid condition-based monitoring.

A Technical Advisory Group (TAG) comprising utility, Institute of Nuclear Power Operations, and original equipment manufacturer (OEM)/vendor personnel provided a thorough review of the report.

Results

This guide includes information on the following topics:

- Fire-resistant fluids
- Fluid purification
- Fluid sampling and analysis
- International Organization for Standardization particle count reported changes
- Condition monitoring
- Trend plots
- Drum storage and fluid makeup
- Material compatibility
- Troubleshooting on various OEM EHC systems
- Operating limits

Applications, Value, and Use

Better maintenance of the EHC system can greatly reduce reoccurring problems. This guide contains comprehensive information that explains the EHC fluid pumping systems and provides solutions for various situations that can occur.

Program

2014 Program 65
Steam Turbines-Generators and Auxiliary Systems

Keywords

Electrohydraulic control (EHC)
Fluid
Fyrquel
Phosphate ester
Reolube

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003594

Steam Turbine Electronic Overspeed Protection System - 3002001060

Product Type: Technical Report Date Published: 23-Dec-13

Background

The risk of turbine-generator destructive overspeed can be mitigated by employing protection systems that act to rapidly isolate the steam supply in the event of separation from the grid. These systems are the final line of defense against overspeed, and they are deployed separately from the systems used to control turbine load and speed during synchronized operation. Most steam turbines in operation today were commissioned with a mechanical trip device that initiates the rapid draining of the trip header when the turbine speed exceeds the emergency overspeed trip point. These mechanical trip devices have proven inherently reliable, but they do require periodic maintenance. In addition, operating experience has shown that surveillance testing using these mechanical trip devices introduces the risk of creating an overspeed event caused by human error. Modern overspeed protection systems employ redundant electronic speed detection systems and hydraulic logic that eliminates single-point vulnerabilities and reduces the potential for human factors to cause an overspeed event.

Objectives

- To provide turbine owners with an understanding of the basic attributes of a modern electronic overspeed protection system with information to consider that may guide the early stages of a retrofit project

Approach

This report is intended to support turbine engineers who are assigned responsibility for assessing upgrade options for existing overspeed protection systems or for the evaluation of systems for new plant construction. A basic explanation of turbine overspeed protection is presented, along with the generic control logic options that are available today in commercial systems.

The advantages of these new electronic overspeed protection systems include the ability to perform surveillance tests at lower speeds, the elimination of single-point vulnerabilities by the use of voting logic, and the incorporation of self-diagnostics and testing. As a result of these advantages, many plants today are electing to convert from mechanical to electronic overspeed protection, according to an industry survey conducted as part of this effort. Discussions with insurers were also conducted as part of this research project.

The insurer feedback indicates strong support for the technical and operational advantages offered by modern electronic overspeed protection and associated mechanical-hydraulic component upgrades.

Results

An analysis of industry operating experience, confirmed by discussions with insurers, reveals that the failure of the stop valves and associated actuators to fully close has historically been the primary cause of overspeed events. The Electric Power Research Institute's perspective is that the modernization of turbine overspeed protection has the potential to reduce the risk of overspeed events. A further benefit is that the potential to use lower speed surveillance test points can reduce turbine life consumption. These benefits are significant, and successful execution requires effective management of the controls-upgrade project. The technical background that is provided in this report will assist in project management of the upgrade. Although significant benefits can be realized from this type of upgrade, it is important for turbine owners to understand that if the maintenance of the stop valves and the actuators is inadequate, simply improving the design of the speed detection and trip logic systems will not substantially reduce overspeed risk.

Keywords

Electric overspeed protection
Risk management
Simulated overspeed testing
Turbine overspeed
Turbine protection systems

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001060

Steam Turbine Valve Actuator Condition Assessment: 2013 Update - 3002001717

Product Type: Technical Report Date Published: 25-Jul-13

Abstract

This report provides nuclear and fossil plant personnel with current information on the inspection and assessment of steam turbine valve actuators. It covers the actuators that are typically found on the turbines of the two major U.S. original equipment manufacturers (OEMs), as well as those of several non-U.S. OEMs. The scope encompasses both mechanical hydraulic control (MHC) and electronic hydraulic control (EHC) types of hydraulic actuators.

Background

EPRI's Program 65, Steam Turbines-Generators and Auxiliary Systems, has developed a series of maintenance guides to assist plant personnel with the performance of tasks associated with a wide variety of plant components. These guides include two large volumes devoted to steam turbine valve inspection and assessment: Guidelines and Procedures for Turbine Valve Condition Assessments (1010211) and Guidelines and Procedures for Condition Assessment of Turbine Valves from Non-U.S. Manufacturers (1023854). The present report (3002001717) is intended to serve as a complement to those two guides. They cover the turbine valves themselves, and the present report covers the associated actuators for the valves. This 2013 update supersedes EPRI report 1015674, published in 2008. It adds information on actuators for valves of several non-U.S. OEMs to the existing body of information covering the manufacturers General Electric and Siemens/Westinghouse.

Objectives

- To provide technical information for the inspection and maintenance of turbine valve actuators
- To provide plant maintenance personnel with the current methods of assembly and disassembly of turbine valve actuators

Approach

A Project Advisory Group (PAG) was formed that consisted of steam turbine owners from members of the EPRI Steam Turbines-Generators and Auxiliary Systems program. Extensive research was performed for the turbine valve actuators used in the industry.

Results

The guide includes a technical description of the turbine control system and components of the actuator assembly. Inspection criteria and data sheets for the recording of measurements and condition of the turbine actuator are included in this report. Preventive and corrective maintenance tasks, applicable procedures, special tooling, and safety considerations are also included.

Application, Value, and Use

The objective of this project was to develop procedures designed to assist plant maintenance personnel in performing proper disassembly, inspection, and reassembly of common nuclear and fossil steam turbine valve actuators. Procedures for actuators included in the guide will assist utility maintenance personnel in planning and performing overhauls of actuator components and assist with quality control of this work if performed by outside parties.

With the continued pressure to reduce outage durations and costs at most utilities, it is imperative to have a planned scope and schedule for all work to be performed within an outage, including work on steam turbine valve actuators. Inspections and rebuilds of steam turbine valve actuators typically occur during planned outage timeframes, and proper pre-outage planning can allow an opportunity in returns of reduced downtime and direct costs.

Keywords

Condition assessment
Hydraulic cylinder
Inspection
Turbine valve
Valve actuator

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001717

Guidelines and Procedures for Condition Assessment of Turbine Valves from Non-U.S. Manufacturers - 1023854

Product Type: Technical Report Date Published: 16-Nov-12

Abstract

This document provides guidelines and procedures for condition assessment and maintenance of large steam turbine valves operated in both fossil and nuclear plants. The document contains a section of basic maintenance guidance followed by a series of procedures detailing the disassembly, inspection, maintenance, and reassembly of specific valve types. Accompanying each procedure is a set of data sheets that are designed to facilitate the collecting and recording of data for the type of valve discussed in that procedure. The data sheets can be readily reproduced for use in the field. This guide covers valves made by Toshiba, Hitachi, and Mitsubishi Heavy Industries and complements EPRI product 1010211, which covers valves from GE and Siemens Westinghouse.

Background

The ongoing effort to shorten outage duration and increase scheduled inspection intervals promotes the need for more effective condition assessment and condition-based maintenance approaches. As the industry continues to transition into these practices, there is a limited window of opportunity to capture the most relevant field expertise on condition assessment that has been amassed in the last 25–30 years. Assembling a concise set of organized procedures is a way to assist staff in the systematic and proper disassembly, inspection, and reassembly of the common nuclear and fossil turbine valves.

Objectives

- To present procedures in sufficient detail to allow utility maintenance personnel to either perform the overhaul of turbine valve components themselves or else control the quality of this work as performed by a vendor

Approach

Industry consultants experienced with turbine valve condition assessment processes contributed the information used in this document.

Results

For each of the selected valve types covered by this guide, a step-by-step procedure with supporting data sheets and detailed specifications is presented. A general overview of basic concepts and principles is also provided. The material can be used as a reference or can be customized for use in a turbine valve condition program at a given plant.

Application, Value, and Use

Participants in the EPRI steam turbine-generator program have provided strong support for this project, as well as for the related seven-volume set titled Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections. Both projects are delivering practical, high-value, industry-reviewed documents that assist plant operators. Many power producers are experiencing technical staff reductions and the loss of experienced maintenance staff. These organizations can apply these guidelines and procedures to assist new maintenance engineers in developing basic proficiency in valve condition assessment and maintenance, in addition to using them as a basis for development of plant-specific documents used to control work operations.

Keywords

Condition assessment
Inspection
Maintenance
Outages
Steam Turbines
Turbine valves

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001023854

Chemical Cleaning of a Turbine Main Steam Stop/Throttle Valve - 1022388

Product Type: Technical Report Date Published: 23-Dec-10

Abstract

Turbine stop/throttle valves control the load and speed of turbine-generator units and are critical for their safe operation. Oxide deposits on the valve stem and bushing reduce the clearance, eventually causing the stem to stick or bind in the bushing. At present, the accumulated oxides are removed by blast cleaning with aluminum-oxide abrasives when the turbine valves are disassembled for inspection.

In an effort to reduce the downtime involved with removing the accumulated oxides, the Electric Power Research Institute contracted with Kinectrics to test various organic solvents for in situ chemical cleaning. The principal findings are listed below:

- The oxide is dominantly magnetite and consists of three distinct layers with total average thicknesses of 119 µm (4.68 mil), 246 µm (9.68 mil), and 621 µm (24.45 mil) for Stems #2, #3, and #4, respectively. The average loading of fixed oxide ranged from 1.2E+02 g/m² (11 g/ft²) to 6.0E+02 g/m² (55.8 g/ft²). The average loading of loose oxide is 3.1E-01 g/m² (2.9E-2 g/ft²).
- The oxide layer may not be uniformly distributed along the entire length of the valve stem.
- Hydroxyacetic formic acid (HAF) is optimal for targeting high iron-oxide deposits, whereas ammoniated ethylenediaminetetraacetic acid (EDTA) and ammoniated citric acid can be more suitable when other constituents, such as copper, nickel, and zinc oxides, are present.
- Increasing the HAF concentration from 2%/1% to 6%/3% will result in greater oxide dissolution in less time with negligible effects on carbon steel C1010, alloy steel C22, and stainless steel 347 materials.
- A 6%/3% HAF solution and a minimum surface-to-volume ratio of 4.4–4.5 m-1 (1.34–1.37 ft-1) is recommended to reduce the oxide thickness by approximately 80% in a 5-h exposure period.
- Based on a 0.9-m (3-ft) valve stem with 0.635-mm (0.025-in) clearance, the in situ oxide surface area (stem exterior plus cavity interior surface) is estimated at 0.22 m² (0.7 ft²). This would require a volume of approximately 50 L (13.2 gal) (6%/3% HAF) to be cycled through the system for a 5-h duration at 93.3°C (200°F).

Keywords

Chemical Cleaning
Citric acid
Glycolic acid
Hydroxyacetic formic acid (HAF)
Magnetite
Turbine valve

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001022388

Steam Turbine Mechanical Hydraulic Control System - Operation, Inspection, Setup, Troubleshooting, and Maintenance Guide, Revision 1 - 1019313

Product Type: Technical Report Date Published: 25-Jun-09

Abstract

This report describes the components of General Electric and Westinghouse steam turbine mechanical hydraulic control systems and provides typical drawings. It focuses on systems located on the front standards and valve enclosures of utility-sized fossil and nuclear steam turbines manufactured by General Electric and Westinghouse. The report is intended to assist in maintaining, calibrating, and troubleshooting these systems.

Objectives

The objective of this report is to provide a single reference that describes the maintenance, calibration, and troubleshooting of General Electric and Westinghouse fossil and nuclear steam turbine mechanical hydraulic control systems.

Approach

This report provides an overview of a steam turbine mechanical-hydraulic control system and its primary components. It also describes outage planning, maintenance, calibration, and troubleshooting procedures.

Results

This report describes the steam turbine mechanical hydraulic system, the common components of the system, the primary subsystems, the tools and documentation required to maintain the system, and the methods and techniques used to inspect, test, calibrate, and troubleshoot the system.

Application, Value, and Use

This report is intended for use by plant personnel who are responsible for maintaining steam turbine mechanical hydraulic control systems.

EPRI Perspective

This report provides information to give plant personnel a better understanding of the steam turbine mechanical hydraulic control system, its components and failure modes, and recommended maintenance practices. In addition, it provides a troubleshooting guide to aid in determining the cause of particular problems and the appropriate corrective actions.

Keywords

General Electric
Mechanical hydraulic controls
Westinghouse
Maintenance
Troubleshooting

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001019313

U.S. Steam Turbine Valve Metallurgy Guide - 1016786

Product Type: Technical Report Date Published: 30-Mar-09

Abstract

This report provides nuclear and fossil plant personnel with current information on the metallurgical aspects of the steam turbine valve components used in U.S. power plants.

Background

The Electric Power Research Institute (EPRI) published the Guidelines and Procedures for Turbine Valve Condition Assessments (1010211) in December 2005. Two topics that would complement the work in the EPRI guide are alternative materials that are used in valve components and the metallurgy associated with the valve materials. This report contains these two topics.

Objectives

- To provide technical information for the use of alternative materials in steam turbine valve stems and bushings
- To provide plant maintenance personnel with the metallurgical aspects of the materials used for steam turbine valve components

Approach

A Technical Advisory Group was formed that consisted of steam turbine owners from members of the EPRI Steam Turbines, Generators, and Balance-of-Plant Program and the Nuclear Steam Turbine Initiative Program. Extensive research was performed regarding the turbine valve materials used in the industry.

Results

The guide includes metallurgical information for the steam turbine valve (stop/governor, control/throttle, reheat stop, and intercept) bushings, discs, pressure seal heads, seats, and stems. The metallurgical topics include alloy standards, chemical composition, physical properties, mechanical properties, heat treatment, damage mechanisms, and repairs.

EPRI Perspective

The reliable operation of the steam turbine valves is crucial for the continued operation of nuclear and fossil generating plants. The metallurgy for the valve components is an important aspect of the reliability of the valve components.

Keywords

Chemical Composition
Damage Mechanism
Life Assessment
Metallurgy
Physical Properties
Turbine valve

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001016786

U.S. Steam Turbine Valve Actuator Condition Assessment - 1015674

Product Type: Technical Report Date Published: 23-Dec-08

Abstract

This report provides nuclear and fossil plant personnel with current information on the inspection and assessment of steam turbine valve actuators.

Background

The EPRI report Guidelines and Procedures for Turbine Valve Condition Assessments (1008352, Interim Report, 2004, and 1010211, Final Report, 2005) provides detailed instruction for General Electric Company- and Siemens-Westinghouse Corporation-supplied valve component inspection and assessment criteria. It is intended that this report (1015674) be a complementary report to the earlier reports. Those reports (1008352 and 1010211) cover the steam turbine valves proper, and the present report covers the associated actuators for these turbine valves.

Objectives

- To provide technical information for the inspection and maintenance of turbine valve actuators
- To provide plant maintenance personnel with the current methods of assembly and disassembly of turbine valve actuators

Approach

A Technical Advisory Group was formed that consisted of steam turbine owners from members of the EPRI Steam Turbines, Generators, and Balance-of-Plant Program and the Nuclear Steam Turbine Initiative Program. Extensive research was performed for the turbine valve actuators used in the industry.

Results

The guide includes a technical description of the turbine control system and components of the actuator assembly. Inspection criteria and data sheets for the recording of measurements and conditions of the turbine actuator are included in this report. Preventive and corrective maintenance tasks, applicable procedures, special tooling, and safety considerations are also included.

EPRI Perspective

The inspection and condition assessment of the turbine valve actuators ensure the integrity of the valve actuators and the continued safe operation of the steam turbine unit.

Keywords

Condition assessment Hydraulic cylinder Inspection
Turbine valve Valve actuator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001015674

Electrohydraulic Control Fluid and Elastomer Compatibility Guide - 1011823

Product Type: Technical Report Date Published: 22-Dec-05

Abstract

The Electrohydraulic Control Fluid and Elastomer Compatibility Guide provides power plant personnel with current information on the compatibility of turbine-generator electrohydraulic control (EHC) fluids and various elastomers, such as hoses, seals, and gaskets. The information in the guide should assist plant personnel in improving the reliability and performance of the EHC system.

Background

EHC systems are used in nuclear and large fossil steam turbine units. Phosphate ester fire-resistant fluids are used as the working fluid in the high-pressure EHC systems on large steam turbine-generator units. These fluids perform well and provide years of trouble-free service when maintained properly. There have been a number of cases, however, when incompatible elastomer materials were used and effects on the elastomers were noted. Because the effect of the incompatible elastomer materials on the EHC fluid had not been researched in the past, the issue became the topic of this report.

Objectives

- To subject various elastomer materials to new and used EHC fluids
- To test the EHC fluids before and after exposure to the elastomer materials
- To document the results of the EHC fluid-elastomer tests

Approach

A Technical Advisory Group (TAG) was formed that consisted of turbine-generator equipment owners from the EPRI Nuclear Steam Turbine Initiative (NSTI) and Program 65 members and several vendors. A survey was sent to the TAG for input on problems with elastomer materials and EHC fluid test results. The TAG members and vendors supplied elastomer materials, new EHC fluids, and used EHC fluids for testing. The elastomer materials were tested for changes in appearance and volume, and the EHC fluid was tested for changes in material properties.

Results

This guide includes general information on the EHC fluids and elastomer materials used in turbine EHC systems. The results of the utility surveys are tabulated and discussed. Any results of discussions with the original equipment manufacturers regarding the use of EHC fluids are included. The results of the elastomer and fluid testing are presented. A summary of conclusions and recommendations for the various elastomer materials are given.

EPRI Perspective

The compatibility of various elastomer materials with the EHC fluid is critical to the reliability of the turbine control system. The effect of using incompatible materials is compounded with extended maintenance intervals. Proper elastomer material selection will ensure EHC fluid integrity and function.

Keywords

Compatibility
Elastomer
Electrohydraulic control
Reliability
Turbine control system

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001011823

Turbine Steam Valve Diagnostic Testing - 1004960

Product Type: Technical Report Date Published: 08-Dec-04

Abstract

A key aspect of reducing operation and maintenance (O&M) costs for power-generating equipment is the adoption of condition-based maintenance. Proper condition assessment is critical to the success of this approach. In support of this goal, this report explores two methodologies for performing condition-based assessments on large steam turbine valves at fossil and nuclear plants. Focus was placed on characterizing a series of industry-identified valve component failures and degradations.

The first condition-based assessment method, periodic diagnostic testing (PDT), is performed while the unit is off-line. It involves the adaptation of proven air-operated valve (AOV) diagnostic test techniques. This report describes an approach for applying a typical AOV diagnostic system to hydraulically operated turbine valves. This guideline reviews diagnostic system capabilities, the available tests that can be performed, and integration of the test system with the valve components. Also described are evaluation methods to identify various expected failures. Detailed kinematic analysis techniques are reviewed that are used to generate a series of simulated diagnostic test output curves characterizing common failure and degradation mechanisms experienced by valves. It is shown how each failure is manifested in the diagnostic test results, which provides a crucial database for future application of this technique by the industry. Lastly, the report describes the diagnostic testing program recently initiated at one U.S. power plant, including a discussion of the various challenges and solutions developed to address implementation issues.

As an alternative to off-line testing of turbine valves, an on-line testing technique is also addressed in the report. This approach uses available sensors on the valve system to provide information that can be analyzed following each surveillance test to assess turbine valve condition. To support this approach, suggested sensors and sample rates are discussed. The report presents examples of on-line turbine valve testing at two U.S. power plants.

Background

Turbine valves are critical elements for providing steam flow control as well as turbine isolation in the event of generator load rejection. Reliable performance of these valves is important for safe and efficient plant operation. As power plants move increasingly toward condition-based maintenance, steam valves are viewed as lacking the required technology to perform condition assessment. As a result, time-based maintenance of steam valves continues to be the most commonly used approach. The industry has identified a need for practical and effective steam valve condition assessment technology in order to optimize valve maintenance.

Objectives

- To propose and demonstrate techniques for assessing the condition of turbine valves that do not require their disassembly

Approach

Diagnostic testing of air-operated process valves in power plants has been successfully used during the past 15 years. This report describes an approach for applying this technique to large hydraulically operated turbine valves. Using this technique, the valve is stroked while the plant is off-line. The stem movement is monitored to detect anomalies and defects in the condition of the valve stem, bushing, springs, and linkages. This project explored methods for on-line valve testing using the periodic valve closure tests to obtain detailed diagnostic data. Kinematic models of valve component motion were developed to study specific types of condition degradation and their anticipated effects on the diagnostic test curves. The resulting database will be useful for interpreting diagnostic data from this class of valves in the future.

Results

Two specific control valve designs were modeled as a baseline condition and with several common valve faults. A comparison of the results shows the expected patterns in the diagnostic test results associated with certain degradation mechanisms. Guidance is provided in this report for the plant modifications needed to conduct this type of periodic diagnostic testing and the online testing performed in conjunction with valve surveillance testing. Example data from three power plants are provided to demonstrate the early application of these methods.

EPRI Perspective

The role of condition-based maintenance in reducing overall plant operation and maintenance (O&M) costs will become increasingly significant in the future. The emerging industry trend toward increased use of equipment monitoring and diagnostic testing has not yet included significant progress on turbine valves. This research project provides the critical first step toward the eventual development and application of valve condition assessment technology. EPRI encourages continued industry use of this technique, collaboration on establishing fleet databases of periodic test results, and interpretation of the data for common design valves. This work complements EPRI's ongoing effort to improve turbine valve maintenance using the Guidelines and Procedures for Turbine Valve Condition Assessments (EPRI report 1008352).

Keywords

Diagnostic Techniques
Steam Turbines
Turbine Life Management
Valves

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001004960

12

GENERATOR TESTING, MONITORING, AND DIAGNOSTICS

Enhanced Interpretation of Electromagnetic Signature Analysis for Large Machines (EMSA) Version 2.0 - 3002004430

Product Type: Software Date Published: 18-Dec-14

Abstract

Software to simulate the frequency response of large utility generators.

Benefits & Value

- Easy interpretation of electromagnetic signature of a generator or motor
- Makes on-line, non-invasive, monitoring cost effective

System Requirements

Windows Vista, Windows 7, Windows 8

Newer Version Of

1022501-Enhanced Interpretation of Electromagnetic Signature Analysis for Large Machines (EMSA) Version 1.1

Keywords

Electric Generators
On-line monitoring
Frequency Response

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004430

Emergency Diesel Generator (EDG) Monitoring and Condition Assessment via Transient Methods - 3002003743

Product Type: Technical Report Date Published: 15-Dec-14

Abstract

In generating stations, as well as any other large industrial complex, steady-state monitoring of plant equipment is an indispensable part of maintaining safe and reliable operation of machinery, systems and processes. The transition to digital systems that capture, transmit and manipulate sensor data opened the door to the implementation of algorithms that can focus on transient conditions. These transients capture, in certain instances, telling signals indicating deterioration of components that otherwise may only become detectable when the deterioration is in more advanced stages.

In this report, a number of techniques are described that can be utilized to monitor both quasi-state signals, as well as transients. One of the strongest drivers for pursuing online monitoring, including monitoring of transients for emergency diesel generator (EDG) application, is the latest trend witnessed in some nuclear power plants to shift their preventive maintenance programs from maintenance based on schedule, to a *condition based maintenance* paradigm. A strong combination of online monitoring, testing and visual inspections are essential for such a change to be successful.

This report makes a number of recommendations that augment the Electric Power Research Institute's (EPRI's) ongoing efforts in introducing online monitoring (OLM) and online monitoring of transients (OLMT) to the nuclear power industry, in particular to the emergency diesel generator systems. The project team reviewed previous projects and commercially available instrumentation and software useful for direct application to emergency diesel generators for online monitoring in general, and monitoring of transients in particular, while considering the unique circumstances confronting emergency diesel generators.

Keywords

Condition monitoring	Emergency diesel generator (EDG)
Online monitoring (OLM)	Online monitoring of transients (OLMT)

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003743

Very Low Frequency (VLF) Hipot Testing of Rotating Machine Stator Winding Insulation - 1021773

Product Type: Technical Report Date Published: 23-Dec-11

Abstract

High-potential (hipot) tests are performed to determine whether winding insulation in rotating electrical machinery has a minimum level of electrical strength to successfully survive electrical stresses in normal service for the expected life of the machine. In recent years, the Electric Power Research Institute (EPRI) has been engaged in helping to clarify industry practices and investigate questions about specific aspects of hipot testing. One topic of interest to the industry is the use of very-low-frequency (VLF) hipot testing, as an alternative to power-frequency ac testing or dc testing. As reliable and relatively inexpensive VLF high-voltage power supplies have become available over the past decade, EPRI has identified the need to provide a quantitative basis for appropriate selection of VLF hipot levels that are suitable for testing of modern synthetic stator winding insulation. This report documents a series of tests conducted to help address this need. Specifically, the objective was to provide electrical breakdown or withstand data to evaluate the validity of a particular numerical factor that has been used to provide equivalence between VLF (0.1-Hz) and power-frequency (60-Hz) hipot testing.

Keywords

Hipot testing
Stator winding insulation
Stator windings
Very low frequency
VLF

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021773

Early Detection of Developing Generator Problems - 1020234

Product Type: Technical Report Date Published: 08-Dec-10

Abstract

The goal of this project is to help utility maintenance and monitoring engineers make optimum use of existing or newly installed on-line monitors to more effectively identify abnormal conditions developing in a generator before a failure or significant damage can occur. Better monitoring can result in improved generator reliability, utility operating costs, the ability to stay on-line during stress events, and operating efficiency. Many large two and four-pole generators have been retrofitted with additional on-line monitors. Most generator owners look at the output of each monitor separately. The project goal is to work with the individual monitor suppliers to document logic rules that can be used to combine the output of continuous monitors to provide higher-level diagnostics. The rules combine such outputs of continuous monitors as flux probe, shaft voltage and current monitor, rotor ground detector, partial discharge, EMI diagnostics, RF monitoring, generator shaft, and end-winding vibration, condition monitors, and conventional operating data. The result is a set of logic rules written in Microsoft Excel™that define the relationships between indications from various monitors and can be used to increase the probability of detecting and confirming symptoms of developing problems. The rules are generic so that the generator owner can tailor them to unit specific levels and situations. This report describes how to interpret and use the Excel spreadsheet rules.

Keywords

Integration
On-line monitoring
Turbine generator

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001020234

Generator Stator Core Condition Monitoring by Tracking Shaft Voltage and Grounding Current - 1020275

Product Type: Technical Report Date Published: 23-Feb-10

Abstract

In order to identify repairable problems early, generator core monitoring must be improved. The primary risks to core integrity are 1) deterioration of core lamination insulation, which results in electrical currents circulating through the core material, causing it to severely overheat and melt, and 2) relaxation of core pressure, which results in fatigue cracking of core laminations.

Generator core condition monitors provide strong indicators of severe overheating of the core insulation. The indication of overheating does not prevent the core damage, but it can limit the consequential damage and identify dangerous operating ranges so that suitable changes in operating procedures and voltage control can be implemented in order to substantially extend the useful service life of the core.

The U. S. Patent 6,460,013 B1 identifies how to detect shorted stator laminations by using shaft voltage and current measurements. Generator operating parameters (temperature, core audible noise and vibration, and the harmonic content of the stator current and voltage), partial discharge tests, generator condition monitors, and other monitoring devices are used to confirm the presence or absence of core defects. The shaft voltage-current monitor based on this patent and manufactured by Magnetic Products and Services was used in conducting the research for this project.

Objectives

The objectives of this project were the following:

- To validate that shaft voltage and current monitoring can be used to detect developing core problems.
- To document how to interpret shaft voltage and current measurements and to recognize and confirm the presence of core problems.

Approach

The approach to this Electric Power Research Institute (EPRI) project was to test and evaluate generators that were suspected of having stator core problems. EPRI sought two- or four-pole generators operating with known or suspected stator core problems to verify that shaft voltage and current monitoring could be used to detect and track core lamination shorts. Generators with core hot spots were monitored for shaft grounding currents and voltages as a means to locate and identify lamination core shorting.

Results

Researchers found that shaft voltage-current monitors can indeed identify shorted stator laminations. This report describes shaft condition monitoring, shaft grounding, and sources of shaft voltage and current. It also explains how to measure shaft voltage and current and how to acquire and interpret the data, including examples and case histories.

Application, Value, and Use

Plant owners and operators can use the information in this report to aid in understanding how shaft voltage-current monitoring can help to avoid premature core replacement.

EPRI Perspective

EPRI's strategic role in on-line monitoring is to facilitate its implementation and use in numerous applications at power plants. On-line monitoring provides better information about the condition of equipment through frequent, accurate evaluation. EPRI is committed to the development and implementation of on-line monitoring as a tool for evaluating instrument or equipment performance.

Keywords

Condition monitoring
Generator core condition
Shaft current
Shaft voltage
Stators

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001020275

Digital Fault Recorders in Power Plant Applications - 1020233

Product Type: Technical Report Date Published: 27-Jan-10

Abstract

This report educates power plant operators on the use of information captured by digital fault recorders (DFRs) in power plant applications.

Background

Since their introduction in the 1980s, digital fault recorders have had a significant role in monitoring the bulk electric power system. As digital monitoring technology continues to evolve, DFR capabilities are being incorporated in devices that have historically performed other functions. By eliminating the need for dedicated monitoring equipment and contributing to a reduction of manpower, these new applications can provide significant cost advantages while helping power plant personnel improve their abilities to identify and diagnose power plant problems.

Objectives

- To provide practical guidance in installing, monitoring, and maintaining digital fault recorders in power plant environments.
- To promote new applications for data captured by DFRs that benefit power producers and electric utilities.

Approach

The project team addresses general capabilities and uses of data captured with fault recording technology to illustrate different approaches for obtaining and applying the technology. While the team discusses different types of technology, their primary focus is on conventional standalone fault recorders; principles and processes the team highlights can be applied to different digital fault recording and disturbance monitoring technologies. The team also presents case studies of how to use fault recorder data in unique ways with the goal of promoting new applications.

Results

The report provides a brief background on the evolution of digital fault recorder technology and a discussion of the different factors involved when installing DFR. In addition to the benefits gained from monitoring with DFRs, regulatory requirements are discussed in terms of the justification for installing monitoring systems. Existing and proposed industry and North American Electric Reliability Corporation (NERC) standards commonly used with DFR captured records are outlined. Data access and interpretation also are covered. Included in the report are case studies highlighting the benefits of monitoring power plants using DFRs.

EPRI Perspective

Generator owners and operators who install dedicated standalone digital fault recorders have the capability to monitor and maintain their plants at a level not available to those who don't have the monitoring capability. As generator operators and owners learn how to make best use of the data available to them, increased operating efficiencies will be realized and improved plant operations will result.

Keywords

Digital recorder
Fault recorder
Plant monitoring
Transients

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001020233

Guide for Rotating Machine Stator Winding Hipot Testing - 1014908

Product Type: Technical Report Date Published: 10-Mar-08

Abstract

High-potential (hipot) tests are performed to determine whether winding insulation has a minimum level of electrical strength to successfully survive electrical stresses in normal service for the expected life of the machine. The expected electrical strength of suitable insulation in most cases is well above the hipot test value. Consequently, a failure during a hipot test indicates that the insulation is unsuitable for service. Though hipot testing has been performed for almost 100 years, questions remain about its use. This report attempts to answer some of those questions.

Objectives

In 2000, EPRI issued a draft report (EPRI report 1000666) on hipot testing, which included an industry survey and a literature review. Since that time, some of the utilities surveyed have changed their hipot testing practices. Several papers also have been published that address issues raised in the 2000 draft report. As a result, EPRI undertook a new survey and reviewed the recent literature. This report re-addresses hipot testing in the light of this recent information.

Approach

The project team's goal was to produce an up-to-date guide for hipot testing of rotating electrical machines. Available literature on the subject was reviewed and a survey conducted. This survey, involving only EPRI members, was analyzed and compared with an earlier survey from 2000 involving various utilities and manufacturers. Results from the literature review and the surveys are summarized in this guide.

Results

The report poses four questions related to the use of hipot tests; the answers to those questions constitute the project's primary focus. These four questions are addressed one by one using results from a literature review and two industry surveys.

Application, Value, and Use

This update to EPRI's 2000 draft report was designed, in part, to answer these four questions:

- When should a hipot test be applied?
- Should ac or dc hipot be applied?
- Does hipot test damage a good winding?
- What should hipot test levels be?

EPRI Perspective

Hipot tests have been used for almost a century, and there are many papers and standards on the subject. It would be reasonable to assume that further work in this area was not needed. However, the need for further R&D became evident when a number of controversies were not resolved, either in the literature or in the survey. For example, one possible topic for further investigation involves determining whether ac or dc hipot testing is better at detecting insulation weakness. Another topic involves reevaluating use of 0.1 Hz voltage as a compromise between power frequency voltage and dc voltage for tests on machines (in particular, determining if the ratio between 60-Hz and very low frequency, or VLF, hipot test levels is valid for all types of insulation).

Keywords

Commissioning
Hipot tests
Stator winding insulation
Stator windings

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014908

Generator On-Line Monitoring and Condition Assessment - 1012216

Product Type: Technical Report Date Published: 11-Dec-06

Abstract

The trend toward lengthening the generator inspection interval and limiting the extent of disassembly for inspection clearly favors greater use of on-line condition monitoring. More accurate assessment of generator component condition is increasingly important to maximizing unit availability and minimizing risk and forced outages. Techniques for partial discharge (PD) detection, in the time domain, or electromagnetic interference (EMI), in the frequency domain, are part of an armory of tools now available to utility engineers for condition-based monitoring. Because the aging of stator insulation is a major factor limiting the life of a high-voltage machine, accurate assessment of insulation system status has become a pivotal issue in reliability and maintenance decisions. This report documents EPRI's initiative to provide utilities with an objective comparison of methods for assessing the condition of stator insulation in large utility generators and their associated peripherals, based on discharge analysis in the PD and EMI domains. The report also includes a specification for PD testing of large utility generators based solely on technical and perceived scientific merit.

Objectives

One of the original objectives of this project was to identify the methods and "best practices" that show the most promise for assessment of utility generators based on PD and EMI monitoring. Experience gained over the last few years involving a variety of methods has provided some basis for evaluating the techniques used. It should, however, be noted that it has always been EPRI's intention that the results obtained using different methods in this program were to be verified through confirmatory inspections of the monitored generators, where the opportunity for inspection was made available.

Approach

The project team analyzed PD and EMI assessments made at Sammis Unit 6 of First Energy Corp. as well as Marshall Units 3 and 4 of Duke Energy. They monitored PD assessments only of Unit 3 at the Lake Road Generating Station in Dayville, Connecticut. All commercial testers contributing to this study obtained PD or EMI data and then applied engineering judgment to the phase-resolved pulse counts or spectral results. Their time-honored yardsticks for evaluation included polarity predominance, phase angles of discharge groups, frequency bands involved, and evidence of cross coupling.

Results

This report is the culmination of a multiyear project to assess the efficacy of a variety of PD and EMI methods for diagnosis of anomalous conditions of the stator insulation structure in large utility turbine generators. Outages scheduled for several machines in the program have permitted inspection and verification of stator winding condition to be undertaken this year. As a consequence, this report not only highlights salient aspects of tests conducted in 2005-06, but also provides an assessment of the strengths and weakness of the various PD and EMI techniques used in light of established machine condition. On the basis of the study, a PD specification is derived and additional insight is provided on how the industry is likely to proceed with computer-based diagnosis in light of these techniques. This report should be read in conjunction with earlier EPRI reports on this subject, 1001209 (2000), 1007742 (2003), 1004958 (2004), and 1010207 (2005).

Application, Value, and Use

The goal of this research was to contrast and compare the effectiveness of PD and EMI techniques for on-line testing of turbine-driven generator stator winding insulation systems. One key challenge arose with the fact that PD measurements in inductive equipment are very difficult to calibrate, and comparison between measurements made with different equipment, gain settings, filters, and couplers are highly problematical. However, comparative measurements—taken either between phases or at different times using the same equipment and settings—are meaningful to assess technology performance and appropriate applications. Over time, it has become clear that the greatest generator operator benefit of either a PD or EMI analysis is the ability to examine unit degradation with respect to baseline signature.

EPRI Perspective

Although PD is a time-domain measurement and EMI measures activity with a frequency scan, both techniques still evaluate the same phenomenon—high frequency currents that flow as a result of electrical (partial) discharges occurring within the structure. Both PD and EMI signatures are complex and often difficult to interpret, particularly in the case of measurements in the frequency domain, where the interpretation of results depends critically on the experience of the individual taking the measurements. To some extent, testers select indices to describe the characteristics or severity of the condition being investigated. Breakdown of the characteristics into meaningful parameters is a valuable and necessary first step on the road to greater use of computer-based intelligence in problem diagnosis. This report represents the fifth in a series of studies aimed at examining the various PD and EMI methods available for evaluation of large utility generators through the use of discharge monitoring.

Keywords

Electromagnetic Interference
On-line Measurement Systems
Stators
Turbogenerators
Windings

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001012216

Generator Expert Monitoring System Knowledge Base - 1011441

Product Type: Technical Report Date Published: 03-Mar-05

Abstract

GEMS (Generator Expert Monitoring System) was designed to be a real-time, on-line monitoring and diagnostic system designed to help operators make optimum use of existing sensor data. Although GEMS is not commercially viable, the report documents the knowledge gained from the project.

Objectives

A recognized need for improved and more comprehensive methods of generator monitoring grew steadily during the early to mid-1980s. Driving this need was the desire to more effectively identify abnormal conditions developing in the generator and its auxiliary systems before a failure or significant damage could occur. Better monitoring could result in improved generator reliability, utility operating costs, the ability to stay on-line during stress events, and operating efficiency and life extension.

Approach

In addition to describing the main features of the GEMS prototype, the project team analyzed results from prototype testing of two GEMS systems on operating units, including a written record of the software's Problem and Indicator databases. The information from the original GEMS project also was updated to recognize recent major generator problems.

Results

This document describes the main features of the GEMS prototype. It includes results of prototype testing of two GEMS systems on operating units along with a written record of the software's Problem and Indicator databases.

EPRI Perspective

When generator alarms occur, operators depend on available information from sensor inputs to determine possible problem sources. To successfully diagnose, operators must be aware of all possible problems, be able to interpret sensor readings—which are often incomplete—and be aware of any suspected problem's consequences. A great deal of generator expertise is needed to avoid generator failures and bring units back online quickly and efficiently. The rules documented in this report can help operators accomplish this task by complementing their own expertise with timely and reliable information.

Keywords

Electric Generators Expert Systems
Monitoring Online Systems
Sensors

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001011441

Assessment of Partial Discharge and Electromagnetic Interference On-Line Testing of Turbine-Driven Generator Stator Winding Insulation Systems - 1007742

Product Type: Technical Report Date Published: 03-Mar-03

Abstract

Partial discharge (PD) and electromagnetic interference (EMI) on-line testing have been promoted as means to assess the condition of turbine-driven generator stator winding insulation systems. Such test approaches offer clear advantages in avoiding prolonged generator shutdown for off-line tests and inspections. Although PD is a time-domain measurement and EMI measures activity with a frequency scan, both techniques still evaluate the same phenomenon -- high-frequency currents that flow as a result of electrical (partial) discharges occurring within the structure. This report documents assessments of the stator winding insulation condition for three generators -- obtained by commercial test companies using PD and EMI techniques. It presents the results of these assessments and an appraisal of the effectiveness of each technique. The report should be read in conjunction with an earlier EPRI report, "Partial Discharge On-Line Testing of Turbine-Driven Generator Stator Windings" (1001209, December 2000), which provided a detailed primer on the mechanisms of machine deterioration and the installation of sensors for detection of discharge activity.

Objectives

The goal of this research was to contrast and compare the effectiveness of PD and EMI techniques for on-line testing of turbine-driven generator stator winding insulation systems. One key challenge arose with the fact that PD measurements in inductive equipment are very difficult to calibrate, and comparison between measurements made with different equipment, gain settings, filters, and couplers are highly problematical. However, comparative measurements -- taken either between phases or at different times using the same equipment and settings -- are meaningful to assess technology performance and appropriate applications.

Approach

One tester evaluated the Sammis Unit 6 stator winding insulation system using installed 1000-pF couplers in the frequency range of 3 - 150 MHz. Assessment was made principally on the basis of a pulse height analysis with polarity discrimination. Another tester evaluated the unit using the EMI technique. Three companies tested the Marshall units' insulation systems using PD detection, and two employed EMI in the frequency domain. In addition, one tester provided an acoustic evaluation of the isophase bus area using a hand-held ultrasonic probe to screen for major sources of electromagnetic noise that could prejudice on-line electrical measurements. All commercial testers contributing to this study obtained PD or EMI data and then applied engineering judgment to the phase-resolved pulse counts or spectral results. Their time-honored yardsticks for evaluation included polarity predominance, phase angles of discharge groups, frequency bands involved, and evidence of cross coupling.

Results

Clearly, the greatest generator operator benefit of either a PD or EMI analysis is the ability to examine the degradation of a unit with respect to a baseline signature. Assessments documented in this report cover a 30-year old Westinghouse generator (800 MVA, 20 kV, H2 cooled) at Sammis Unit 6 of Ohio Edison (now FirstEnergy Corp.) as well as similar GE generators (790 MVA, 24 kV, H2 cooled) at Units 3 and 4 of the Marshall Plant of Duke Energy Corporation. Key findings include the following:

- It is not always easy to acquire unambiguous information from signatures available at machine terminals, as such signals are often corrupted by noise. Perhaps the most effective way to reduce noise is to use two sets of couplers per phase and then apply time-of-flight methods to discriminate against pulses entering from outside the machine.
- Other useful techniques for reducing noise impact include setting a threshold for PD counting and establishing a background frequency scan to identify FM broadcast stations. Furthermore, an acoustic scan of the bus ducts can detect noise and would seem to be a quick and worthwhile additional test.
- Discharge characteristics are known to change as a result of both loading and power factor changes. Systems able to monitor activity over a period of time in which such changes take place clearly add another dimension to the diagnostic process.

EPRI Perspective

Both PD and EMI signatures are complex and often difficult to interpret, particularly in the case of measurements in the frequency domain, where the interpretation of results depends critically on the experience of the individual taking the measurements. To some extent, testers select indices to describe the characteristics or severity of the condition being investigated. Breakdown of the characteristics into meaningful parameters is a valuable and necessary first step on the road to greater use of computer-based intelligence in problem diagnosis. This report takes that first step in the field of generator stator winding insulation systems.

Keywords

Electromagnetic Interference
On-line Measurement Systems
Online Systems
Stators
Turbogenerators
Windings

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001007742

Large Air-Cooled Generators Driven by Combustion Turbines: Generic Issues - TR-107723

Product Type: Technical Report Date Published: 16-Apr-97

Abstract

Since the mid to late 1980s, the number and size of large combustion turbine driven generator sets have greatly increased. While generators over 100 MVA were formerly all hydrogen-cooled, many of the new large units utilize air-cooled systems with ratings as high as 300 MVA. This report provides a discussion of issues relating to the procurement of large air-cooled combustion-turbine generators and related equipment.

Background

In the late 60s and early 70s, significant increases in generator sizes led to low reliability and limited availability at many plants as this step size in unit capability exceeded available technology. To avoid a repeat of these problems with today's large air-cooled generators, EPRI has sponsored a project to summarize the state-of-the-art in air-cooled generator technology and provide a basis for procurement guidelines for large air-cooled generators and related equipment.

Objectives

- To develop generic guidelines for procurement of large air-cooled combustion turbine generators.
- To develop generic guidelines for procurement of monitoring, diagnostic, and protective equipment for large air-cooled generators.

Approach

The project team reviewed the available literature on large air-cooled generator technology, including relevant ANSI and CIGRE standards, and analyzed the technical approach being taken by various manufacturers in the production of large air-cooled combustion turbine generators. The team comprehensively evaluated the generic issues that affect generators from a system standpoint and conducted an availability and reliability study covering all 50 MW and larger generators. The team used the results of these studies as the basis for guidelines for the procurement of large air-cooled generators and related equipment.

Results

The report discusses the current state of air-cooled combustion turbine generator technology, including a comparison of air-cooled generators with hydrogen-cooled units of comparable rating. It reviews ANSI standards applicable to air-cooled generators along with issues relating to temperature limits, ventilation and cooling methods, and requirements for abnormal conditions. The report lays out the technical bases for design and manufacturing recommendations in the Procurement Guidelines, including generator design constants such as short circuit ratio and power factor that impact unit and system performance during power system disturbances. The technical bases for monitoring, diagnostic, and protective equipment guidelines are also discussed. The report also covers the maintenance and repair of air-cooled combustion turbine generators.

Two appendices give procurement guidelines for air-cooled combustion turbine generators and accompanying monitoring, diagnostic, and protective equipment. While the guidelines define generally accepted measures that have been taken to prevent or mitigate certain known problems that can occur on large air cooled generators and specific features are recommended, they are not a purchase specification. The guidelines apply specifically to air-cooled generators driven by combustion turbines rated 80,000 kVA and higher, but they may also be applied to similarly rated air-cooled generators driven by steam turbines that are part of combined cycle systems.

EPRI Perspective

The power densities of large air-cooled generators are approaching those of hydrogen-cooled generators on a kVA/LB basis. The manufacturers of the new air-cooled generators have used a variety of diverse but generally proven technologies to achieve these efficiencies. Accordingly, the guidelines in this report emphasize functional aspects and the avoidance of known problems rather than the pros and cons of particular technical approaches.

Keywords

AC Generators
Combined-Cycle Power Generation
Combustion Turbines
Equipment Specifications
Procurement
Turbogenerators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-107723

13
TURBINE-GENERATOR GRID INTERACTION

Strain-Based Turbine Generator Torsional Vibration Monitoring System–Phase 3: Prototype Field Application - 3002006234

Product Type: Technical Report Date Published: 29-Sep-15

Abstract

Shaft torsional vibration in power production turbomachinery can be induced by electrical grid transient disturbances and negative sequence currents. The resulting dynamic torque transmitted to the generator rotor can excite several vibration modes of the entire shaft system, particularly those near twice the grid frequency. If undetected, these vibrations have the potential to accumulate fatigue damage in highly stressed rotor elements such as turbine blades, couplings, and retaining rings. Torsional vibration testing and monitoring is now part of the loss control standards stipulated by insurers. In response to this need, EPRI has developed and demonstrated a prototype wireless torsional sensor that measures shaft surface strain as a basis for assessing torsional vibration amplitude and frequencies.

Prototype hardware embodiments of the design concept proposed in 2013 were fabricated and lab tested in 2014. The research has proven that the technology is at a high readiness level, with no significant reliability issues discovered during the 10 unit-months of sensor operation to date on two commercial generating units.

Keywords

Natural frequencies
Shaft torsional vibration
Steam turbine generators
Strain gage telemetry
Torsional testing
Turbine blade failure

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006234

Strain-Based Turbine Generator Torsional Vibration Monitoring System – Phase 2: Prototype Development - 3002003495

Product Type: Technical Report Date Published: 15-Dec-14

Abstract

Shaft torsional vibration in large steam turbine-generator units can be induced by transient grid disturbances and negative sequence currents. The resulting dynamic torque transmitted to the generator rotor can excite several vibration modes of the entire turbine-generator shaft system, particularly those that are near twice the grid frequency. If undetected, these vibrations have the potential to accumulate fatigue damage in highly stressed rotor elements, such as turbine blades, couplings, and retaining rings. Torsional vibration testing and monitoring is part of evolving loss control standards stipulated by insurers. The Electric Power Research Institute (EPRI) has developed the concept for a wireless torsional sensor that measures shaft surface strain as a basis for detecting vibration amplitude and frequencies. The design objectives for the EPRI torsional sensor development project include high sensitivity, low power consumption, minimal spatial requirements on the shaft, quick installation, and the capability for long-term operation. A design concept that meets these objectives was developed and reported by EPRI in 2013.

This report covers the prototype development and initial field installation of the EPRI turbine-generator torsional vibration sensor. Prototype hardware embodiments of the design proposed in 2013 have been fabricated and were lab-tested in 2014. In addition, this hardware has been installed on a 750-MW commercial generating unit at a host power plant. This 2014 field installation demonstrated the feasibility of the process for reliably securing the instrumentation to the shaft, as well as the deployment of the stationary telemetry hardware suitable for use in a plant environment. This host site opportunity will enable EPRI to demonstrate operation of the new sensor and data acquisition system in early 2015, when the unit returns to service.

Keywords

Natural frequencies
Shaft torsional vibration
Steam turbine generators
Strain gage telemetry
Torsional testing
Turbine blade failure

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003495

Strain-Based Turbine Generator Torsional Vibration Monitoring System - Phase 1: Concept Development - 3002001054

Product Type: Technical Report Date Published: 20-Dec-13

Abstract

Shaft torsional vibration in large steam turbine-generator units is induced by transient grid disturbances and negative sequence currents. If undetected, these vibrations can accumulate fatigue damage in rotor elements such as turbine blades, couplings, and retaining rings. Shaft natural frequencies can be closely aligned with the predominant torsional excitation that occurs at twice the grid frequency, amplifying the resulting vibratory response. Calculation methods have evolved that predict shaft natural frequencies during the design phase so that damaging resonance conditions can be avoided. These calculation methods have inherent uncertainties that result in the need for large natural frequency avoidance zones relative to the twice the grid frequency excitation. If these avoidance zones cannot be met when replacing turbine generator rotors, measurements on the operating unit must be performed to verify safe operation. Cost-effective and reliable technology for measurement of shaft natural frequencies on operating units is, therefore, a valuable means for ensuring safe margins relative to twice the grid frequency. The ideal technology should be installed and used with minimal impact on plant operations and be sufficiently rugged to survive long-term monitoring duty.

This report describes proposed new technology for measurement of shaft torsional vibration that is based on strain gage telemetry. Using state-of-the-art microelectronics and a semiconductor strain gage, the size and power consumption of the proposed sensor system is significantly reduced compared to conventional strain gage telemetry. This size reduction removes the need for a clamped collar attached to the shaft as well as the need for a bulky stationary antenna system, greatly simplifying the installation process. The integrated strain gage and data transceiver system will be deployed on a flexible printed circuit board designed to adapt to a wide range of shaft diameters. A low-profile Kevlar composite band is proposed as a method for attaching the electronics to the shaft and providing protection from damage.

Keywords

Avoidance zones
Natural frequencies
Rotor fatigue damage
Shaft torsional vibration
Steam turbine generators
Strain gage telemetry

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001054

Abnormal Negative Sequence Analysis Excel Application Version 1.0 - 1017492

Product Type: Software Date Published: 29-Nov-10

Abstract

The Abnormal Negative Sequence Analysis Excel Application can be used to estimate the likely impact of any electrical event on the generator rotor so that a quick informed decision can be made about generator rotor inspection.

This project is intended to develop an Excel based application that can be used for assessing the need for turbine generators to be inspected after an abnormal negative sequence or motoring from standstill event may have occurred.

- Microsoft™ 2000, XP, and Vista running either Microsoft Office 2003 or 2007

Application, Value, and Use

- Quickly assess the risk of allowing the unit to operate safely after such incident
- Risk assessment does not require access to OEM proprietary data
- Improve unit availability

Keywords

Generator rotor
Generator unbalanced load
Negative sequence

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001017492

Power Plant Model Validation Using On-Line Disturbance Monitoring - 1017801

Product Type: Technical Update Date Published: 07-Dec-09

Abstract

This report is a technical update of recent results of EPRI base funded research work related to on-line model validation and derivation for power plants, conducted under Program 40.001 Load and Generator Modeling. The work is follow-on work from the EPRI R&D program that was published earlier this year in the report Automated Model Validation for Power Plants Using On-line Disturbance Monitoring, EPRI report 1016000 (2009).

Objectives

Historically, it is well understood that the turbine-governor portion of the power plant model is perhaps the most simplistic. This study was conducted to see if some simple modifications to the turbine-governor model for large steam-turbine governors could help to improve the ability to simulate the response of coordinate boiler-turbine units to system disturbances. The project also looked at some other issues such as model validation using recorded responses to unbalanced faults.

Approach

The approach taken was to investigate the potential for fitting boiler-turbine models for large steam-turbine generator response to system disturbances in the MATLAB® environment, using the algorithms developed in the EPRI PPPD tool—see Power Plant Parameter Derivation (PPPD) Software User's Manual: Version 2.0, EPRI report 1017803 (2009).

Results

The technical update outlines the latest lessons learned from the on-line disturbance based model validation technique developed by EPRI.

Application, Value, and Use

This report updates work on model validation using data captured by event recorders, such as digital fault recorders (DFRs), in the power plant during systemwide disturbances. These data are used to validate and fine-tune the power plant model. The benefits are that there is no need to schedule time for testing the unit, the unit need not be maneuvered or taken off-line, and there is no additional risk of damage to the unit. Another key benefit is that the unit's response to actual events is seen. However, for this process to work, good baseline data on the applicable models for the power plant are required, hence the need for some form of staged testing or model validation upon plant commissioning.

EPRI Perspective

EPRI's involvement in synchronous machine parameter testing goes back to the 1980s and 90s with the advent of stand still frequency response-based parameter estimation techniques and the PIDAS project. This report is part of an ongoing effort by EPRI to investigate not only state of the art in power plant model parameter derivation, but also to keep such efforts focused on meeting the needs of the industry as dictated by reliability standards while at the same time keeping the approach to such work as simple, practical, and effective as possible.

Keywords

Disturbance monitoring
Field testing of power plants
Generator model validation
Generator testing
Power plant model validation
Synchronous machine testing

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001017801

Automated Model Validation for Power Plants Using On-Line Disturbance Monitoring - 1016000

Product Type: Technical Report Date Published: 31-Mar-09

Abstract

The report documents the results of the Electric Power Research Institute (EPRI) base-funded research work conducted under Program 40.004, Generator Dynamic Model Parameters Identification and Validation, and Program 65, Steam Turbine Frequency Response Modeling and Validation Using Ambient Monitoring. Because of their synergies, these two projects were conducted in parallel, and this single report presents the results of both projects.

Background

Generator model validation and testing is certainly not a new subject. Efforts have been ongoing in this area for many decades. In 1997, the Western Electricity Coordinating Council (WECC) started a major effort, in the aftermath of the 1996 system breakups, to improve system planning models. One aspect of this was the mandated testing of generating units. The North American Electric Reliability Council (NERC) is working to bring similar mandates to bear nationwide.

In 2007, EPRI's Power Delivery & Utilization (PDU) sector performed a supplemental research project (cosponsored by FE, Duke Energy, and TVA) to develop a prototype software tool for power plant parameter derivation using field-recorded data for staged testing of generating units. This tool caused a significant reduction in the engineering time needed for model parameter derivation and validation. The subject report, Power Plant Modeling and Parameter Derivation for Power System Studies: Present Practice and Recommended Approach for Future Procedures (1015241), provides the background for such staged testing procedures. The report Automated Parameter Derivation for Power Plant Equipment for Use in Power System Studies (1016251) provides a detailed account of the prototype software and demonstrates its use for several staged tests performed on various synchronous generator power plants.

The goal of the 2008 Program 40.004 base-funded research work in PDU was to further extend this prototype software to illustrate whether data collected by on-line disturbance monitoring equipment in a power plant (such as a digital fault recorder [DFR]) could be used for model validation rather than staged testing. The benefit of such a methodology is that it enables the routine revalidation of models without the need to bring the unit off-line to perform staged tests. This allows for compliance with the imminent NERC standards with significantly reduced risk to the units and less cost. The goal of the 2008 Program 65 project was to look specifically at developing such disturbance monitoring–based methods for model validation of the primary frequency response of large steam turbine generators. Because of their synergy, these two projects were performed in unison.

Objectives

The main challenge with this type of model validation is that it typically has been achieved through staged testing of the generating facility. This requires bringing the unit off-line, connecting appropriate recording devices to it, and performing a series of staged maneuvering actions of the unit off-line and at low loads on-line. This incurs expense both in the engineering time and effort required for the task and in the potential loss of opportunity to sell power while the unit is under test. Furthermore, though quite low, there is always a risk of damage to the unit. This project investigated and identified methods of model validation using data captured by event recorders (such as DFRs) in the power plant during systemwide disturbances. These data are then used to validate and fine-tune the power plant model. The benefits are that there is no need to schedule time for testing the unit, the unit need not be maneuvered or taken off-line, and there is no additional risk of damage to the unit. Another key benefit is that the unit's response to actual events is seen. However, for this process to work, good baseline data on the applicable models for the power plant are required—so some form of staged testing or model validation upon plant commissioning is still needed. These topics are all discussed in detail in this report.

Approach

A tool was developed using the MATLAB® environment, and a simple graphic user interface (GUI) was built on top for ease of use. This tool was then used to post-process digitally recorded disturbance data from three volunteer plants to demonstrate and verify the approach.

Results

The results are encouraging: the tools are able to effectively validate power plant models using on-line disturbance data. As expected, however, some expertise on the part of the engineer using the tool is needed to ensure that the proper model structure is chosen for each case and that reasonable initial estimates of the parameters and upper and lower bounds on the parameters are chosen. Furthermore, a good baseline model is of vital importance for the process. Such baseline models may be in the form of detailed manufacturer-supplied models and model verification upon commissioning the plant or models derived during a staged test. The imminent NERC standards (and existing WECC standards) for revalidating power plant models every five or more years can be easily met through such a disturbance monitoring–based methodology. For one of the volunteer units, five system events were captured during a seven-month period.

EPRI Perspective

EPRI's involvement in synchronous machine parameter testing goes back to the 1980s and 1990s with standstill frequency response–based parameter estimation techniques and the PIDAS project. This report is part of an ongoing EPRI effort to investigate not only state-of-the-art power plant model parameter derivation, but also to keep such efforts focused on meeting the industry needs as dictated by reliability standards while keeping the approach to such work as simple, practical, and effective as possible.

Keywords

Disturbance monitoring
Field testing of power plants
Generator model validation
Generator testing
Power plant model validation
Synchronous machine testing

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001016000

Generator Control Testing to Certify Reactive Power Capability, Excitation System Functions and Frequency Response - 1014911

Product Type: Technical Report Date Published: 29-Nov-07

Abstract

There is renewed interest in issues surrounding power system reliability following several major power outages that occurred on the West Coast of the North American power system in the late 1990s and in the Northeast in 2003. One area identified as requiring improvement was in the configuration and reporting of the capabilities, protection, and control of synchronous generators that form the primary source of supply. The U.S. Energy Policy Act of August 2005 contains provisions that make compliance with the North American Electric Reliability Corporation (NERC) standards mandatory and enforceable.

Accurate simulation models of power system equipment are beneficial to all power system participants in order to maximize equipment availability, minimize losses, avoid interruptions, and protect equipment, to name just a few objectives. The required level of detail, best methods to obtain data, and frequency of verification are just some of the issues encountered when trying to obtain and maintain these models. To complicate matters, there is no one method to obtain the desired information that applies to all types of equipment, schedules, and budgets. There is, however, a body of available techniques that can be used to meet these goals, and this report summarizes them and describes the benefits and drawbacks of each.

The report is organized into sections based on the draft standards that were in place as of its writing. These standards are presently in the process of being re-drafted; however, the technical descriptions and engineering approach described are relevant regardless of the final form of the regulatory requirements.

Objectives

This report has been written for generation owners and market participants who work with them on meeting technical regulatory compliance requirements. Section 5 of the report has been written to facilitate the creation of a compliance structure within an organization. Sections 1 through 4 provide a resource for engineering staff involved in analytical support, testing, or simulation of generators and their associated controls.

Approach

This report is based on a compilation of information obtained from generation owners, consultants, industry standards, related technical references, regional entities, and NERC. The project and report are intended to summarize the current approach and best practices that pertain to NERC generator standards while realizing that the standards are actively evolving. This was accomplished for this project through interviews and surveys, interaction with NERC and the NERC standards committees, and input from a technical advisory group that was comprised of generator owners and market participant representatives.

Results

For generation owners with limited experience in the areas of technical compliance with NERC requirements or with generator equipment testing and modeling, this report provides a blueprint for constructing their own compliance program. By using proven practices of other owners and consultants, readers can quickly identify techniques and organizational structures that best suit their organization. Readers will learn that many of the tools required to comply with the emerging requirements already exist in any large, modern generation company.

This report also covers some basic ambient monitoring concepts and applications. The continuation of this project and subsequent reports will address current developments and concepts in ambient monitoring (the recording of unit responses to system disturbances, rather than the use of staged testing as a means of verification of simulation models). Future work in this area should identify the recording requirements and also the minimum complement of signals required to validate various control system models.

Application, Value, and Use

The technical regulatory requirements that apply to generation owners were being re-drafted as the report was in progress. The techniques and practices described here will need to be reviewed and updated based on any changes. Once the requirements have become entrenched and the requirements become mandatory, all generation owners will have to participate in this work, creating a market for innovative solutions and services.

EPRI Perspective

In addition to the EPRI report 1015241, Power Plant Modeling and Parameter Derivation for Power System Studies: Present Practice and Recommended Approach for Future Procedures, this report is a comprehensive compilation of information associated with the NERC technical requirements applied to generator owners. By drawing on EPRI's membership and resources, EPRI has been able to provide an accurate picture of the present best practices applied by the largest utilities throughout North America.

Keywords

Ambient monitoring	Compliance
Coordination	Excitation limiter
Excitation System	Frequency response
Governor	Model
Protective relay	Reactive power capability
Real power capability	Regulatory requirement
Staged test	Synchronous generator
Valid	

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001014911

Interaction Between Electrical Network Phenomena and Turbine-Generator Shafts - 1013460

Product Type: Technical Report Date Published: 04-Dec-06

Abstract

The report documents the results of a literature review, surveys, and detailed sensitivity analysis (using a generic system model with real turbine-generator shaft models) to document the interaction between electrical network disturbances and torsional modes of turbine-generators. The key challenge is that much of this interaction depends on the actual torsional modal response of the unit and the endurance limit of the shaft material.

Background

To study the effects of grid disturbances on turbine-generators requires gathering and sharing event data between transmission system planners, operators, and power plant staff. In today's deregulated environment, this has become a more difficult task. The torsional behavior of steam turbine-generators is explained in EPRI report 1011679. This report examines grid events that can cause torsional fatigue in turbine-generator shafts and low-pressure turbine blades.

Objectives

- To identify the zone of vulnerability of large steam-turbine generating units to torsional interactions due to network switching phenomena and other devices on the transmission system.

Approach

The team performed three tasks. A literature review was conducted to identify all the various sources of torsional interaction phenomena. This review-together with an historic account of events that have been reported to result in damage to turbine-generator shafts in the literature-has been documented here. The second task was to conduct a survey, followed by phone interviews, of large steam turbine-generator owners in the United States to learn if they had recently experienced events that they believe may have led to severe torsional interactions. This also is documented. Finally, a generic power system model was developed and into it incorporated a model of two real turbine-generators (one 1800-rpm and one 3600-rpm unit). Using this model, the team performed a sensitivity analysis related to network switching phenomena (based on the literature search and phone interviews) to identify key factors that influence torsional interaction between the network and the turbine-generator shaft. The goal was to identify the zone of vulnerability for the study units and, hence, determine what general lessons may be learned from this process.

Results

The study has formalized a systematic approach for identifying the zone of vulnerability of a power plant to the potential of damaging torsional interactions. The approach is based on comparing the peak transient torques observed for various network faults and disturbances to the peak transient torque for a machine terminal fault. In addition, the report provided significant insight into the various factors that influence the level of torsional interaction and how to assess when detailed torsional interaction studies are necessary.

EPRI Perspective

EPRI's involvement in monitoring, material testing, and root cause analysis of torsional vibration issues and incidents goes back to the early 1980s. This report complements the tutorial report 1011679 and provides qualitative risk assessment of 1800/3600-rpm steam-turbine and generator torsional interaction with the electrical network.

Keywords

Torsional interaction
Torsional vibration

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013460

Steam Turbine-Generator Torsional Vibration Interaction With the Electrical Network - 1011679

Product Type: Technical Report Date Published: 14-Nov-05

Abstract

This Tutorial Report deals with steam turbine-generator torsional vibration arising from interaction with the electrical systems that connect to the generator. Besides providing background material on torsional vibration and fatigue, it reviews operating experience and machine torsional duty mitigation strategies and provides information on torsional vibration measurement, monitoring, diagnostic procedures, and non-destructive evaluation (NDE).

Background

Several major failures involving fatigue fractures of both shafts and turbine blades led to a serious study of turbine-generator torsional vibration interactions with the power network by electric utilities and turbine-generator manufacturers. Starting in 1971 and up to the early 1990s, EPRI and others conducted projects to develop the required analytical tools and fatigue estimation methodologies, to capture experience with monitoring systems, and to conduct tests on operating turbine-generators. IEEE, CIGRE and others established working groups to study the subject and provide reports and recommendations to the industry. Since the early 1990s, however, relatively little attention has been given to the subject and much knowledge and experience has been lost with the passage of time. Recent torsionally induced cracking problems and turbine blade failures have spiked renewed interest in the subject from utilities, regulators, and manufacturers. This tutorial document is designed to fill the technical understanding void by providing a single document that summarizes torsional vibration information and machine failure experience.

Objectives

- To provide a comprehensive tutorial introduction to the nature and consequences of steam turbine-generator torsional vibration arising from interaction with the electrical systems that connect to the generator.

Approach

Drawing on published information, the project team produced a tutorial introduction to turbine-generator electro-mechanical interactions suitable for plant engineering managers, system engineers, corporate turbine/generator specialists, regulators, and engineering managers. The team included a case study that explores the possible consequences of uprating a turbine-generator as it relates to torsional duty.

Results

Besides providing educational material on torsional vibration and fatigue, the tutorial reviews operating experience. It describes and analyzes the root causes of first-of-a-kind failures and identifies the turbine-generator components most vulnerable to damage by torsional vibration.

The report reviews machine torsional duty mitigation strategies and provides information on torsional vibration measurement, monitoring, diagnostic procedures, and NDE. Some important takeaways from the report:

- The turbine-generator components most vulnerable to torsionally induced fatigue damage are low pressure turbine blade stages in four pole (4P) machines; rotor shaft extensions at regions of high stress concentrations such as keyways, radial holes, and fillets; and generator retaining ring shrink fit surfaces.
- To minimize the risk of torsionally induced fretting fatigue at generator retaining ring shrink fit surfaces, it is important that the shrink fit pressure is high enough in service to avoid relative motion of the rings and the rotor.
- Machines must generally be designed to avoid having responsive torsional vibration modes with natural frequencies close to frequency components that persist in the generator air-gap torque waveform during transients.
- Turbine-generators can be safely uprated from a torsional perspective if appropriate analysis (involving testing in some cases) is performed and modifications/replacements made to some components to improve the capability of the machine.
- In turbine-generator uprating/upgrading programs in which rotors are modified or replaced, it is vital that suitable analysis/testing work be performed to demonstrate that responsive turbine-generator modes will not be brought into torsional resonance.
- Because of the greater potential for inaccuracies in torsional system analysis calculations, torsional testing should be considered at start-up on "hybrid" machines that may result from rotor replacements in machine upgrading and/or uprating programs.
- Torsional vibration monitoring should be employed for machines at power plants where there is potential for a high level of torsional interaction with the power system to exist under "normal operating conditions."

EPRI Perspective

EPRI's involvement in monitoring, material testing, and root cause analysis of torsional vibration issues and incidents goes back to the early 1980s. Other publications on torsional vibration include EPRI reports TR-106640 and 1007001. This tutorial report is intended for individuals who may not have been previously exposed to any torsional vibration issues or incidents, but now need to have an understanding of the multi-disciplinary issues involved.

Keywords

Fatigue
NDE
Root-Cause-Analysis
Torque-Amplification
Torsion
Vibration
Vibration diagnosis

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001011679

Measurement of Ancillary Services From Power Plants: Regulation, Load Following and Black Start - TR-114246

Product Type: Technical Report Date Published: 10-Dec-99

Abstract

In the deregulated electric utility industry, it is anticipated that many ancillary services will be sold by "generators" to Operating Authorities (OAs) or Independent System Operators (ISOs). Such trade in ancillary services will require contractual agreements, and these agreements will need to specify quality and quantity of service to be supplied. This, again, means that it will be necessary to certify or measure the quality of an ancillary service to be supplied, as well as the quantity actually supplied. Towards that end, this report describes methodologies for measurements of ancillary services of Regulation, Load Following, and Black Start.

Background

The ancillary services considered here have been supplied for many years by utilities. But the supply was probably established in a less formal way than now planned. For example, the load following capability of a unit was established by a utility or control area from experience and programmed into the utility's or area generation control's dispatching algorithm. In the future, the Operating Authority (OA) or Independent System Operator (ISO) will not own any of the generating units or direct them to supply the required ancillary services. Rather, they must contract and purchase the necessary ancillary services of the correct performance, and in the required amount, to make sure that reliability and performance will stay within applicable criteria.

Objectives

- To interpret the certification requirements and performance testing drafted by NERC into practical procedures that can be performed routinely for a generating unit, using to greatest possible extent existing station instrumentation.
- To demonstrate certification and performance measurement in the field for each of the two services.
- To evaluate the data and report on the testing in a form that can be used by "generators" as a guide to performing the certification and performance testing at their own installations.

Approach

The general approach was to work with a utility interested in learning how to measure ancillary services and use existing instrumentation and data acquisition equipment to the greatest extent possible. This was to achieve a practical and economical method for measurements. For both services Regulation and Load Following, the equivalent of certification testing was performed. The test patterns were selected so that they could also be used to demonstrate performance. Black Start being a very complicated procedure, it was not possible to find an appropriate test site in 1999. Therefore, only the methodology is covered in this report. Test results will be covered in a future addendum.

Results

A field test was conducted on a steam unit equipped with a digital coordinated boiler turbine control system connected to the area generation control. The unit responded satisfactorily to the load patterns, generated by the control center, used to evaluate the unit's performance as a regulating or load following generator. The performance criteria proposed by NERC for these two ancillary services was evaluated and found to be within expected ranges. It is our opinion that the unit could be certified to supply the ancillary services of Regulation and Load Following.

EPRI Perspective

This report describes methodologies for measurements of Regulation, Load Following, and Black Start, ancillary services. It is anticipated that such, and other services, will be sold by "generators" to Operating Authorities (OAs) or Independent System Operators (ISOs). Such trade in ancillary services will require contractual agreements, and these agreements will need to specify quality and quantity of service to be supplied.

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-114246

14
TURBINE COMPONENT LIFE ASSESSMENT AND RISK MANAGEMENT

High-Temperature Steam Turbine Components-Life Assessment Technologies – 3002008573

Product Type: Technical Results Date Published: 22-Dec-16

Abstract

Many electric utilities with aging steam turbines operating mostly in fossil power plants are looking at various business scenarios and options for the future, including the operation of existing units beyond their nominal design life. This interim report provides an overview of steam turbine life assessment processes, including a description of the main damage mechanisms by component; equipment condition and remaining life assessment activities; and integration of these assessment activities with existing maintenance and life extension programs.

During the next phase (Phase 2) of this project, a survey will be conducted regarding the state-of-the-art technologies used by various service providers in the last ten years to conduct the life assessment of high-temperature steam turbine components. The results of this survey, as well as a description of all the identified state-of-the-art methodologies, their technical advantages and limitations, and best practices in turbine component life management, will be provided in the project's final report, scheduled for release in 2017.

Program

2016 Program 65 Steam Turbines-Generators and Auxiliary Systems

Keywords

Asset management
Condition assessment
Steam turbine
Fossil
Remaining life

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008573

Turbine Generator Risk Management Resource (TGRMR), Version 1.0 – 3002008547

Product Type: Software Date Published: 19-Dec-16

Abstract

The EPRI Turbine Generator Risk Management Application **is a browser-based application meant to be accessed via the web from EPRI's secure servers.** It includes web-pages based on the ASP.net 4.0 framework that will store and retrieve password-protected information from a SQL Server 2008 server.

Plant System Engineers will use the risk management web tool to search for, collect, and reference information related to risk assessment and mitigation by using a combination of equipment hierarchy filters, other risk-related attribute filters, and key word searches.

Benefits and Value

Plant System Engineers will reference this tool as a result of the need to:

- Research an observed anomalous trend;
- Respond to a damage mechanism discovered during an outage; or
- Prepare risk management contingency plans.

Platform Requirements

- Microsoft Windows 7, Windows 8.1, Windows 10
- Microsoft Internet Explorer
- Mozilla Firefox
- Google Chrome

Keywords

Turbine generator
Software application
Risk management
Browser-based application

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008547

Crack Growth and Arrest in High Temperature Valve Bodies - 3002006311

Product Type: Technical Report Date Published: 31-Dec-15

Abstract

This report summarizes the progress for providing improved guidance for the assessment and disposition of cracks detected in stationary components, such as steam turbine casings and valve bodies. It includes a thorough examination of the industry experience and trends and a study of the effect of crack growth on relief of thermal stresses and the driving force for cracking. The historical information feeds the understanding of conditions most prone to cracking while the crack growth study is intended to quantitatively demonstrate the stress relief effect for future application to the steam turbine casing cracking problem.

Cracks in steam turbine casings, sometimes well in excess of a foot in length, seldom propagate to failure. The significant casing cracks are primarily a result of the relief of thermally driven stresses as the crack grows into the wall. Likewise, high temperature valve bodies typically develop cracks that are then monitored at outages and selectively repaired based on the experience and discretion of the owner. The crack arrest phenomenon, although widely recognized, is not easily predicted. Currently, the only way to determine if a casing or valve body crack has arrested and is non-propagating is to perform a detailed thermal stress and fracture mechanics analysis.

This study is aimed at an understanding of, foremost, the historical evidence describing cracking location and propensity, as well as the effect of crack advance on the driving force for cracking from thermal stresses due to thermal gradients. It is anticipated that the results of this study, combined with the categorization of the cracking experience, will help provide a means of estimating the risk of failure of a cracked casing or valve body without having to perform a unit-specific detailed stress and fracture mechanics analysis.

Results and Findings

This report describes the common mechanisms and manifestations of cracking and gives the results of the finite element stress analyses of a three-dimensional semi-elliptical circumferentially-cracked simplified valve body model with an imposed thermal gradient and a growing crack. The aspect ratio of the crack was fixed at 5:1, while several geometrical parameters were varied in the three dimensional model. In particular, the effect of the diameter, wall thickness, seat radius, and bowl radius were investigated.

Generally speaking, the bowl and seat radius had little effect on the crack behavior. The increased constraint provided by the smaller diameter valve combined with a thinner associated wall thickness tended to decrease the driving force for crack growth, particularly for shallower cracks. The driving force for crack growth was higher for thicker walled valves, particularly for shallow cracks. Once the crack depths reached over half the wall thickness, the effect of the geometrical factors is diminished and the crack-tip stress intensity factor approaches zero for cracks with a crack depth of 0.8 times the wall thickness.

Overall, regardless of the particular geometry, after reaching a maximum, the crack-tip stress intensity factor that drives crack growth under thermal stresses is found to decrease with continued crack advance. The decrease in driving force is a result of the thermal stress relief due to the crack. The analyses produced several insights into the crack arrest phenomenon that may be extended toward development of a set of criteria for determining whether a given crack is non-propagating without having to resort to a detailed analysis.

Challenges and Objectives

Extending the results of this study to a broad range of steam turbine valve cracking behavior is a challenge and will require categorization of the experience in terms of combinations of the primary variables (e.g. thermal gradient, section thickness, geometric features, etc). The objective is to ultimately have a set of rules that can be applied to any given casing cracking situation in order to enable quick and efficient run/repair/replace decisions.

Applications, Value and Use

This preliminary study offers a demonstrated basis for further development of a simplified method to assist the plant owner-operator with making run/repair/replace decision on a cracked steam turbine valve body.

EPRI Perspective

This study is part of the effort to develop guidelines for plant owner-operators to make decisions on whether to run/repair/replace a cracked steam turbine valve. It is anticipated that an extension of the work of this study in concert with categorization of the body of turbine casing cracking experience will produce sufficient information to develop the cracked valve disposition guidelines.

Approach

This effort utilizes a simplified three-dimensional semi-elliptical circumferentially-cracked valve body model with an imposed thermal gradient, analyzed for a growing crack via the finite element method. The range of variables chosen is expected to be sufficient for extension of the results to the field application.

Keywords

Fracture Mechanics
Cracking
Stress intensity factor
Steam turbine valves
Thermal stress
Stress relief

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006311

Turbine Generator Risk Management Resource: Development Report - 3002003501

Product Type: Technical Report Date Published: 22-Dec-14

Abstract

This technical report is the first of a series of reports that cover the development of a resource to assist plant asset owners in managing aggregate risk, that is, failure and unavailability, on turbine-generator systems. The turbine-generator asset represents significant operational and maintainability risk from in-service failures and unavailability. The multi-year project will develop and populate a web-based information repository that can inform a risk management program. The information contained in this tool will consist of risk severity, technical basis, mitigation options, operating experience, references, and industry best practices. This report will provide the tool concept, user interaction, description of information, and outputs.

Risk management requires up-to-date knowledge of risk elements, potential severity, and mitigation strategies. Risk analysis methodology typically incorporates identification of contributing component failures, unit operating anomalies, and service life analysis to provide decision-making guidance for the plant engineer. Industry events, failures, and trends will be evaluated against the technical basis functionality to inform the user when significant challenges to reliable service life may exist. The complexity of the turbine-generator and auxiliary support system interactions requires thorough evaluation of all influences to safe reliable operations and service life. The industry is experiencing an aging operating fleet, significant unit cycling, and extended inspection intervals that will challenge the operating staff in making timely and thorough evaluations. This Electric Power Research Institute project will particularly benefit new system engineers by supplementing their experience.

Keywords

Turbine generator
Risk management
Aggregate risk
In-service failures
Risk analysis methodology
Unavailability

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003501

LPRimLife v2.1 - 1018705

Product Type: Software Date Published: 19-Nov-09

Abstract

The LPRimLife software is used for evaluation and life assessment related to steam turbine rotor disk rim cracking.

The goal is to update the existing LPRimLife code to current standards using Microsoft.net technology.

Platform Requirements:

- Windows™ 2000/XP/Vista

Application, Value, and Use

- Provide utility personnel with a tool to estimate the remaining life of an LP rotor disk rim with known or suspected cracking
- Assessment of remaining life allows utilities to do effective maintenance planning
- Assessment of remaining life gives utilities options to implement short-term fixes for continued unit operation

Keywords

Disk Rim Attachment Cracking
Low Pressure Steam Turbines
LPRimLife

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001018705

SAFER-PC Version 2.2, Stress and Fracture Evaluation of Rotors - Personal Computer, Version 2.2 - 1013044

Product Type: Software Date Published: 22-Dec-06

Abstract

The Stress and Fracture Evaluation of Rotors—Personal Computer (SAFER-PC), Version 2.2 software will evaluate the remaining life of steam turbine and generator rotors. Version 2.2 is an upgrade of existing analysis software.

SAFER-PC combines transient thermal-elastic finite element stress analysis, fracture mechanics, material property data, and the clustering and linking of surface defects identified from nondestructive examination (NDE) data to assess remaining usable life of steam turbine or generator rotors. SAFER-PC can also perform probabilistic analysis of remaining life and material creep. Modules are included which allow the import of boresonic NDE data in any format to generate a flaw file. A flexible approach to curve fitting fracture toughness data is also available. SAFER-PC's powerful user interface enables the program to be easily run on a number of current operating systems, with a variety of options for displaying and archiving analysis results.

Platform Requirements

- The following hardware and software are required:
- Windows 2000 or XP
- Pentium-class PC with 1 GHz or faster CPU
- Minimum 512 MB or RAM; 200 MB disk space
- CD-ROM drive

Application, Value, and Use

SAFER-PC can be used to assess the remaining life of critical rotating equipment in life extension studies, potentially savings millions of dollars in replacement rotor costs.

SAFER-PC can reduce uncertainty in risk analyses of older turbine-generator rotors, reducing the possibility of rotor burst that is an issue involving both a safety and consequential cost.

Many plants are being cycled more frequently, and with larger daily variations in steam temperatures. SAFER-PC can evaluate the increased rate of damage associated with this mode of operation, enabling a more accurate assessment of the costs and benefits of flexible plant operation.

Keywords

Life Extension	Remaining life of rotors
Rotor analysis	SAFER-PC

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013044

15
TURBINE THERMAL PERFORMANCE

Steam Turbine Performance Engineer's Guide - 1019657

Product Type: Technical Report Date Published: 23-Dec-10

Abstract

The Steam Turbine Performance Engineer's Guide is meant to present the steam turbine performance engineer with the expected and important functions and responsibilities necessary to succeed in this position that are not necessarily taught in college. The instructions and recommendations in this guide, when properly executed, will improve the effectiveness of steam turbine performance engineers, positively affecting both the performance and reliability of the steam turbines under their care.

Background

The importance of power plant performance has been recognized recently because good performance can reduce fuel costs and reduce CO2 emissions. The steam turbine is the workhorse of most power plants. Its performance and reliability relate directly to the performance and reliability of the power plant that it serves. The actions of the turbine performance engineer are crucial to its high level of performance. However, in many cases, that engineer is assigned many other duties and/or is an early career engineer placed into this position without previous experience.

Power plants and power-generating companies with structured or active performance programs have typically been industry leaders in reliability and performance.

Objectives

- To provide a description and the frequency of the performance engineer's periodic activities
- To supply technical information to serve as a reference manual
- To make recommendations on steam turbine and performance-related training

Approach

In cooperation with interested EPRI members, the project team developed an outline for a guideline describing the activities of a successful turbine performance engineer. The expertise to develop the guide was identified in a contractor who developed draft guides based on experience and industry standards and references. Several EPRI members reviewed these drafts and provided recommendations for the fine-tuning needed to maximize their usefulness.

Results

This comprehensive guide was developed by drawing on decades of industry expertise. It contains the program structure for the coordinated actions necessary to maintain or improve steam turbine performance and reliability. The guide provides the details for engineers serving in this capacity to successfully and positively affect the performance and reliability of steam turbines.

EPRI Perspective

Stations with a performance program perform better than those without one. A performance program provides the data for decision making with respect to timely maintenance. Monitoring the performance of a steam turbine includes the trending of parameters that also describe the performance of other plant components, providing insight and information on improving their operation. A performance program creates a culture centered on improving plant performance. The sharing of performance data with the entire plant staff strengthens their understanding of how each staff member may contribute, making the improvement of plant performance a team effort.

Through the use of this guideline, EPRI members should be able to establish and maintain a turbine performance improvement program and ultimately improve component performance and unit heat rate.

Keywords

Heat Rate
Performance engineer
Performance program
Steam turbine
Turbine performance
Turbine system engineer

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001019657

Evaluation of Currently Available Steam Turbine Steam Seals - 1022249

Product Type: Technical Report Date Published: 27-Oct-10

Abstract

With the rising cost of fuel and the strong possibility of CO2 emission regulations and limitations in the near future, utilities and power generation companies are focusing on power plant performance and costs. Improvements in plant performance—which lowers fuel costs and decreases emissions—can make a difference in the financial health of a power plant, a power company, and the power industry as a whole. Turbine seals play an important role in maintaining and improving turbine performance.

Background

The steam turbine is the workhorse of most power plants. Its performance and reliability relate directly to the performance and reliability of the power plant it serves. The turbines steam seals are crucial to its high level of performance. However, the seals are made to wear or fail rather than cause damage to the turbine rotor during transient events.

As the time between steam turbine major overhauls has increased, the useful life of the steam seals must follow that trend by increasing several years or leave the power plant owner or operator with greater efficiency losses for several years between turbine overhauls. Turbine steam seals have advanced in response to the needs of power plant owners and operators. More robust and innovative designs have entered the marketplace in the last two decades. In addition, power plant owners and operators have installed these new seals in their turbines in hopes of preventing early failure and reaping efficiency benefits.

Objectives

- To describe currently available turbine seals, their historic and expected performance, and cost-benefit evaluation

Approach

The approach for this report was to conduct an evaluation of currently available turbine steam seals, focusing on different seal types, independent of vendors. The evaluation was based on capital and maintenance costs, physical attributes, historical data, expected life, and effect on turbine performance.

A determination of the needs of the industry with respect to turbine steam seals was made. Comparing those needs to the seals currently available, the gaps were then identified, and a vision or attributes of the steam seal of the future was proposed.

Results

This report contains detailed descriptions of currently available turbine seals. Descriptions of seal function and performance are included.

EPRI Perspective

The results of these analyses will help power plant owners and operators in their quests to improve plant performance and minimize costs. This knowledge of the various available seals will enable those power plant owners and operators to make informed decisions with respect to their turbine hardware. The reliability and peerformance of turbine seals relate directly to the reliability and performance of the steam turbins in which they reside, which, in turn, contribute to the overall performance and reliability of the power plants they drive. Therefore, the improvement of turbine seals has a direct effect on the bottom line of the operation of a steam power plant.

Keywords

Gland seals
Interstage seals
Steam seals
Steam Turbines
Turbine performance
Turbine seals

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001022249

Routine Performance Test Guidelines for Steam Turbines - 1021483

Product Type: Technical Update Date Published: 02-Sep-10

Abstract

With the rising cost of fuel and the strong possibility of CO2 emissions regulations and limitations in the near future, utilities and power generation companies are focusing on power plant heat rate and performance. Improvements in heat rate, which lower fuel costs and decrease emissions, can make a difference in the financial health of a power plant, a power company, and the power industry as a whole. A set of 10 routine test guidelines was developed in 2009. Using the same methodology, an additional set of nine routine test guidelines was developed in 2010 for the periodic performance testing of power plant components and systems. This report contains two of those new test guidelines that relate to steam turbines.

Background

Good plant performance programs include testing for determining the health of its components and systems, troubleshooting problems, and optimizing performance. However, due to both cost and staff reductions, testing in power plants has become less frequent despite the importance of optimizing plant heat rate and performance in an era of rising costs and looming CO2 emission regulations. ASME Performance Test Codes (PTCs) provide procedures for the rigorous tests typically used for acceptance testing of new equipment, but such testing is conducted very infrequently because of its very high cost. In order to provide its members and the industry as a whole with another tool to improve plant performance, the Electric Power Research Institute (EPRI) undertook the development of routine test guidelines, providing less expensive tests that produce results with more uncertainty than the PTCs tests but that can be used more frequently.

Objectives

- To provide a set of routine test guidelines for the periodic performance testing of power plant steam turbines

Approach

In cooperation with interested EPRI members, the project team developed a list of routine tests of plant performance for which guidelines have been developed over a two-year period and defined a standard outline for test guidelines. As the first part of a plan to produce a full set of 15-20 guidelines over two-year period, in 2009 the team developed routine test guidelines for 10 separate actions or tests based on industry experience and best practices. In this second year of this effort, the team developed draft routine test guidelines for another nine different separate actions or tests, with two focused solely on steam turbines. As in 2009 a large group of utility engineers and industry experts from EPRI members reviewed these drafts and provided recommendations for the fine tuning needed to maximize their usefulness.

Results

These guidelines were developed to permit reliable testing of steam turbines that can produce repeatable results. These routine tests can be conducted without major financial or time investments. They are designed to be conducted with a minimal number of people and to produce results that can be used for trending, analyzing, troubleshooting, and optimizing the performance of individual pieces of power plant equipment. Power plant personnel can use the guidelines to conduct tests using common test instruments to generate the primary data with process instruments meeting the remainder of the data requirements.

The procedures in this document are designed for the following purposes:

- Long-term trending of key performance parameters
- Identifying problems
- Troubleshooting component or system problems
- Optimizing component or system operation and performance

It should be noted that these guidelines are not intended for use in establishing baseline performance and boundary conditions for retrofit projects or for evaluating contract performance guarantees.

EPRI Perspective

Conducting routine performance tests is an important component of a good plant performance program. The information contained in this report represents a significant collection of information and instructions, including techniques and good practices, related to conducting routine performance testing of power plant steam turbines.

Through the use of these guidelines, EPRI members should be able to conduct routine tests more frequently, improve the results of those tests, and ultimately improve component performance and unit heat rate.

Keywords

Heat Rate
HP-IP interstage leakage
Performance Test
Steam Turbines
Thermal Efficiency

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021483

Routine Performance Test Guidelines - 1019004

Product Type: Technical Update Date Published: 10-Aug-09

Abstract

With the rising cost of fuel and the strong possibility of CO2 emissions regulations and limitations in the near future, utilities and power generation companies are focusing on power plant heat rate and performance. Improvements in heat rate, which lower fuel costs and decrease emissions, can make a difference in the financial health of a power plant, a power company, and the power industry as a whole. This report provides a set of routine test guidelines for the periodic performance testing of power plant components and systems. Ten separate test guidelines are presented in this report. An additional set of routine test guidelines will be developed using the same methodology, and issued in 2010.

Background

Good plant performance programs include testing for determining the health of its components and systems, for troubleshooting problems, and for optimizing performance. However, due to both cost and staff reductions, testing in power plants has become less frequent despite the importance of optimizing plant heat rate and performance in an era of rising costs and looming CO_2 emission regulations. ASME Performance Test Codes (PTCs) provide procedures for the rigorous tests typically used for acceptance testing of new equipment, but such testing is conducted very infrequently because of its very high cost. In order to provide its members and the industry as a whole another tool to improve plant performance, EPRI undertook the development of routine test guidelines that provide for less expensive tests that produce results with more uncertainty than the PTCs tests but can be used more frequently.

Objectives

- To provide a set routine test guidelines for the periodic performance testing of power plant components and systems

Approach

In cooperation with interested EPRI members, the project team developed a list of routine tests of plant performance for which guidelines will be developed over a 2-year period and defined a standard outline for test guidelines. As the first part of a plan to produce a full set of 15-20 guidelines over 2-year period, the team developed draft routine test guidelines for ten separate actions or tests based on industry experience and best practices. A large group of utility engineers and industry experts from EPRI members reviewed these drafts and provided recommendations for the fine-tuning needed to maximize their usefulness. Additional test guidelines covering other components, systems, and techniques will be developed and issued in 2010.

Results

These Test Guidelines were developed to permit reliable testing of power plant components that can produce repeatable results. These routine tests can be conducted without major financial or time investments. They are designed to be conducted with a minimal number of people and produce immediately usable results. Power plant personnel can use the guidelines to conduct tests using common test instruments to generate the primary data with process instruments meeting the remainder of data requirements.

The procedures in this document are designed for the following purposes:

- Long-term trending of key performance parameters
- Problem identification
- Troubleshooting component or system problems
- Optimizing component or system operation and performance

It should be noted that these guidelines are not intended for use in establishing baseline performance and boundary conditions for retrofit projects or evaluating contract performance guarantees.

EPRI Perspective

Conducting routine performance tests is an important component of a good plant performance program. The information contained in this report represents a significant collection of information and instructions, including techniques and good practices, related to the conduct of routine performance testing of power plant components and systems. The components and systems that may be evaluated by this set of tests include:

- Air Heaters
- Cooling towers
- Feedwater heaters
- Steam condensers
- Steam turbines

Through the use of these guidelines, EPRI members should be able to conduct routine tests more frequently, improve the results of those tests, and ultimately improve component performance and unit heat rate.

Keywords

Air Heaters
Condensers
Cooling Systems
Cooling Towers
Cycle Isolation
Feedwater Heaters
Heat Rate
Performance Test
Steam Turbines
Thermal Efficiency

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001019004

16
TURBINE NON-DESTRUCTIVE EXAMINATION RESEARCH

NDE Methodology Applied to Turbine Components: Phase Array Examination of Long-Shank Straddle-Mount Disk Attachments - 3002005860

Product Type: Technical Report Date Published: 23-Dec-15

Abstract

This report summarizes the results of a study evaluating the feasibility of performing phased array ultrasonic examination of low-pressure steam turbine straddle-mount disk attachments after long-shank repairs as a result of stress corrosion cracking. The study compared the pre-repair and post-repair examination feasibility for various styles of common straddle-mount disk attachments.

Background

An increasing number of low-pressure steam turbines with straddle-mount disk attachments have experienced stress corrosion cracking in the blade attachment region. For attachments that have been repaired by the long-shank modification method, there is concern that future phased array ultrasonic examination is unfeasible after long-shank repairs because of the reduction of accessible disk surfaces, irregular surface geometries, and interference from balance holes. Advanced ultrasonic phased array inspection is the only practical nondestructive evaluation method for inspection of straddle-mount blade attachments without blade removal.

Objective

Through the use of advanced ultrasonic simulation and modeling software, the feasibility of phased array ultrasonic testing (PAUT) of straddle-mount disk attachments after long-shank repairs was explored.

Approach

This evaluation compared pre-repair and post-repair examination feasibility for various styles of common straddle-mount disk attachments. PAUT simulation software provides a realistic image of the ultrasonic beam’s interaction within the disk attachment. It also provides a visual representation of beam coverage, aids understanding of echoes arising from geometry and defects, and helps foresee unexpected echoes. Several limiting factors—including surface geometry, wedge design, and transducer selection—will ultimately determine the feasibility of simulated techniques. Flaw response for each disk attachment model will be simulated for several commercially available phased array probes to evaluate probe frequency and aperture effects.

Results

The work carried out as part of this project used the latest development and simulation software tools to explore the possible methods of advanced inspection of common straddle-mount disk attachments after machining of the disk attachment region from long-shank repair. The disk designs evaluated have very different geometries and disk dovetail symmetry but share in the regions of highest risk and technical challenges to enact repeatable, sensitive, and reliable inspection techniques. Several popular off-the-shelf transducer configurations were selected to explore defect response.

Applications, Value, and Use

This report is intended primarily for personnel who are responsible for planning or overseeing steam turbine attachment examinations. It provides general information on phased array ultrasonic examination of straddle-mount blade attachments after long-shank modifications.

Keywords

Nondestructive evaluation (NDE)
Phased array
Low-pressure rotor
Scan planning
Long-shank disk
Straddle-mount

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005860

Digital Radiography for Turbine Pin Finger Blade Cracking Detection - 3002005990

Product Type: Technical Report Date Published: 21-Dec-15

Abstract

This report describes the work done to date to develop a nondestructive evaluation (NDE) technique using digital radiography to detect cracking in steam turbine rotor pin finger blade attachments. The report covers trials using digital radiography, a study of radiation and its management during on-site examination, assessment of the feasibility of performing the examination at a central workshop facility, and blind testing of the radiographic examination technique using a sample provided by the Electric Power Research Institute (EPRI).

Background

The current method for examining turbine pin finger blade attachments requires removing each blade from the rotor. Following the examination, the reassembly process involves machining the holes to enable new pins to be securely fitted. This is an expensive procedure, the time and cost of which can be greatly reduced by an NDE technique that allows examining the blade roots without removing the blades.

Objectives

The objective of this project was to develop and validate a digital x-ray NDE technique for examining turbine pin finger blade attachments on the L-0 stage of the rotor without disassembling the turbine blades.

Approach

The work was structured into the following five stages:

1. Develop the examination technique by imaging in the laboratory a sample set of five turbine blade pin finger roots with engineered defects, using high-energy digital x-ray equipment.
2. Test and evaluate radiation emission from the high-energy x-ray source to determine the requirements for radiation shielding for safe use during an examination at a power station or turbine maintenance shop.
3. Assess the deployment requirements to examine turbine pin finger blade attachments.
4. Validate the imaging performance using a second sample with engineered defects known only to EPRI, with the results being judged by EPRI to determine which defects were identified and which were not.
5. Test the system and equipment by examining the L-0 stage of the rotor on a turbine at a maintenance workshop.

Results

Stages 1 through 4 were successfully completed, and stage 5 is scheduled to be completed in December 2015. The digital x-ray technique performance was proven on an engineered sample in the laboratory in tests for which EPRI provided oversite and assessment of results, and the configuration of a safe and practical solution for use at a power station or turbine maintenance shop was determined.

Applications, Value, and Use

The report will be of value to operators of turbines with pin finger blade attachments to understand the cost and time savings that can be achieved by NDE of turbine pin finger blade attachments without physical disassembly and removal of the turbine blades.

Keywords

Nondestructive Evaluation
Turbine blades
High-energy x-ray
Pin finger attachments

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005990

Phased Array Performance Demonstration for Disk Steeple Radial-Axial Cracking: Blind Trial - 3002003503

Product Type: Technical Report Date Published: 16-Dec-14

Abstract

Ultrasonic technology has been used to examine turbine disk blade attachments since the 1990s. In 2005, EPRI collaborated with commercial inspection vendors to successfully demonstrate phased array techniques for the inspection of steam turbine tangential-entry disk blade steeples. The initial development focused on tangential-entry blade dovetail and the detection of circumferentially oriented cracking along the steeple. Recent utility outages have reported visible cracking in the radial-axial (RA) direction across the steeple. This report features an evaluation of the Structural Integrity Associates' phased array technique for the detection of RA cracking in tangential-entry steeple.

Background

Numerous documented cases of RA cracking in General Electric–style disk-rim blade dovetails (steeples) have been reported over the years, although not believed to be as common as circumferential cracking due largely to the relatively low stresses in the axial direction. RA cracks are primarily found in the L-2 and L-3 stages of tangential-entry turbine disks, and occurrences may be on the rise, perhaps aided in part by an aging fleet.

RA cracking is thought to start on the underside of the top hook at locations of surface pitting. Due to their orientation, RA cracks may be easily missed by current disk-rim inspection practices that focus the sound beam favorable to the detection of circumferential cracking but parallel to the direction of RA cracking.

For this reason, the application of phased array ultrasonic testing for tangential-entry disk steeples was developed in 2005 to primarily address circumferential cracking rather than RA cracking. The concerns of plant owners are whether standard phased array ultrasonic testing had missed RA cracking in past inspections and what must be done in the future to ensure that inspections cover both types of potential cracking on this disk configuration.

Challenge and Objective

The objective was to evaluate the suitability of phased array ultrasonic technology for the detection of RA cracking in tangential-entry disk blade steeples.

Approach

EPRI invited Structural Integrity Associates to participate in a blind phased array ultrasonic inspection performance demonstration for the detection of RA cracking in a service-removed tangential-entry blade attachment disk. The selected EPRI mockup contained service-induced circumferential cracks along the dovetails. Man-made embedded RA flaws that varied in size and depth were used for this demonstration.

EPRI Perspective

As the domestic turbine fleet ages, the incidence of RA cracking in the tangential-entry blade steeple has become more common. This report provides guidance for utility staff who contract phased array ultrasonic inspection services for the examination of tangential-entry blade dovetail steeples. The results of this demonstration indicate that effective detection of RA cracking in the tangential-entry blade steeples by phased array ultrasonic inspection techniques is possible. This demonstration also determined that additional research is needed to improve depth and length sizing capabilities.

Keywords
Steam turbine
Phased array ultrasonic inspection
Turbine blade attachment inspection
Radial-axial disk cracking
Tangential-entry turbine disks

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003503

Phased Array Examination Methodology for Curved Axial-Entry Turbine Blade Attachments - 3002001318

Product Type: Technical Update Date Published: 22-Oct-14

Abstract

The report provides both an overview and step-by-step approach for performing a simulated phased array ultrasonic testing (PAUT) inspection on curved axial-entry blade root designs. The use of PAUT simulation software provides a realistic image of the ultrasonic beam's interaction within the blade root. It also provides a visual representation of beam coverage, aids understanding of echoes arising from geometry and defects, and helps foresee unexpected echoes. Several limiting factors—including access, inter-blade spacing, wedge design, and transducer selection—will ultimately determine the feasibility of simulated techniques.

Background

Steam turbine blades are subjected to significant stresses during normal operation, which have been known to result in cracking in the dovetail (fir-tree) attachment regions. Cracking in low-pressure curved axial-entry turbine blades can severely impact safe operations because of the large mass and size of these blades. Most current nondestructive evaluation (NDE) techniques require rotor deblading, which is a time-consuming process. Without deblading, the only currently available NDE technique is ultrasonic phased array of the attachment blade root. However, the detection and sizing capabilities of the ultrasonic phased array method are limited by the complex geometry in the curved axial-entry blade attachments.

Objectives

This report presents a step-by-step process for using ultrasonic simulation software for performing beam and defects computation within the turbine blade root. Through the use of advanced ultrasonic simulation, it can be proven that the inspection of critical areas of blade roots is possible without dismantling them from the rotor.

Approach

This report focuses on the last-row (L-0) blades of low-pressure turbines from Siemens and Alstom. The target blade roots consisted of the 13.9 m2 blade from Siemens and the ND37 blade from Alstom. Complex three-dimensional (3-D) models of the blades were generated and used to determine the theoretically optimum scanning positions and beam angles.

Inspections using advanced ultrasonic methods of this type require an engineered approach to develop sensitive, repeatable techniques that have high probabilities of detecting the initiating defects. The process includes the use of modern design and simulation tools to develop targeted inspection techniques for highly complex geometries, followed by extensive validation on blade samples with simulated defects. Once defect detection is validated, techniques, scanning aids, and procedures are designed and implemented to provide a sensitive, repeatable and reliable inspection solution.

The ultrasonic simulations were carried out using CIVA modeling software. CIVA was developed by the French company CEA in conjunction with several industrial and academic partners and facilitates full ultrasonic beam and defect interaction simulation with 3-D computer-aided design (CAD) models. CIVA was used to comprehensively simulate the possible inspection techniques required to target the blade root geometries.

Results

The work carried out as part of this project used the latest development and simulation software tools to explore the possible methods of advanced inspection of two different blade root attachment designs. The designs have very different dimensions and blade root symmetry but share in the regions of highest risk and technical challenges to enact repeatable, sensitive, and reliable inspection techniques. Several popular off-the-shelf transducer configurations were selected to explore defect sensitivity in a variety of axial and radial positions. Available surfaces for probe placement were investigated, and the minimum defect size for both the concave and convex root curvature was calculated.

Applications, Value, and Use

Significant cost savings can be achieved by the deployment of in situ inspection techniques. Critical regions of the axial-entry fir-tree blade roots could be successfully inspected, offering equivalent coverage and crack detection to surface inspection methods.

Keywords

Phased array
Low-pressure rotor
Nondestructive evaluation
Curved axial entry
Scan planning
Turbine blade root
Ultrasonic simulation

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001318

Turbine Casing Crack Depth Sizing by Phased Array - 1025334

Product Type: Technical Update Date Published: 14-Dec-12

Abstract

The average age of coal-fired power plants in the United States has passed 35 years. As the power plants age, more and more cracks emerge and grow in turbine casings, including shells and valve bodies. Crack depth sizing is an extremely important task for an accurate remaining life assessment and the effective life management of turbine casings. Because of the complex geometries and large thicknesses of turbine casings, current crack depth sizing techniques have a low accuracy. The objective of this research is to investigate the phased array ultrasonic technique for crack depth sizing and demonstrate the process to achieve a high accuracy of depth sizing.

A retired turbine shell and a valve were acquired as the test samples for this research. Then computer-aided design models were developed for the phased array simulations. Notch flaws were fabricated in both samples and used in the phased array simulations and experiments. Different test parameters were compared in the simulations to achieve the optimal depth sizing accuracy. Experiments were conducted based on the optimal parameters and sizing errors were analyzed. Finally, recommendations were provided to achieve the optimal crack depth sizing accuracy in the field applications.

Keywords

Crack depth sizing
Phased array ultrasonic testing (PAUT)
Turbine casing crack

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001025334

Phased Array Performance Demonstration for Axial-Entry Blade Attachment Examination - 1021586

Product Type: Technical Update Date Published: 24-Apr-12

Abstract

Phased array ultrasonic technology has been used to examine turbine disk blade attachments since the 1990s. The initial development focused on tangential-entry blade attachments. After successful field application on tangential-entry blade attachments, recent research efforts have focused on axial-entry blade attachments. Due to the complex geometries, axial-entry blade attachment examination is more challenging. To further investigate phased array examination technology for axial-entry blade attachments, the Electric Power Research Institute (EPRI) organized a performance demonstration in which two well-established nondestructive evaluation service companies examined three retired turbine disks. Notch flaws had been manufactured in the blade attachment areas in all three disks.

This report summarizes the analyses of the examination results. The overall results on axial-entry blade attachment examinations show significantly greater challenges compared to previous results on tangential-entry blade attachment examinations. Research can be conducted to further improve the current detection and sizing capabilities, including optimization of scan configurations, curvature correction, and flaw fabrication to simulate service-induced cracks. However, geometric limitations will still exist, especially for small, curved axial-entry blade attachments.

Keywords

Axial-entry turbine blade attachment
Phased array ultrasonic technique
Steam turbine disk rim examination
Tangential-entry turbine blade attachment

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021586

Nonlinear Ultrasonic Measurements Using a Capacitive Probe for Pre-Cracking Fatigue Damage Detection in Steam Turbine Blades - 1021779

Product Type: Technical Update Date Published: 22-Dec-11

Abstract

Fatigue is a common damage mechanism of steam turbine blades. Early detection of fatigue damage can significantly increase the safety margin and decrease maintenance costs during steam turbine operations. An advanced nondestructive evaluation technique—nonlinear ultrasound—showed promise in detecting fatigue damage before the onset of visible cracks.

A nonlinear ultrasonic measurement system based on a capacitive probe was built to measure the material nonlinearity in fatigue specimens. Compared to a piezoelectric ultrasonic probe or an electromagnetic acoustic transducer, a capacitive probe provides better measurement accuracy with much less inherent nonlinear noise. To verify the accuracy of the measurement system, benchmark measurements were conducted on single-crystal copper and fused silica specimens; the results agreed with published values in the literature. Additional measurements were made on SS304, Al7075, and GTD111<110>.

After the successful benchmark measurements, a series of stainless steel type 410 specimens with different fatigue cycles were measured. The nonlinear ultrasonic measurement results exhibited a statistically significant difference between specimens with less than 40% fatigue life and 40% or more fatigue life. The absolute difference in these readings, however, is small even for the lab-based system. Modifying the lab system for field use is expected to provide larger scatter in measurements and will likely reduce the ability to discriminate damage levels in steam turbine blades.

This report begins with background information and then describes a nonlinear ultrasonic measurement system, benchmark measurements, the design and mechanical testing of fatigue specimens, and nonlinear ultrasonic measurements of fatigue specimens. The report concludes with a summary of results.

Keywords

Capacitive probe
Nonlinear ultrasonic technique
Pre-cracking fatigue damage
Steam turbine blades

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021779

Detection of Generator Shaft Keyway Cracking - 1015256

Product Type: Technical Update Date Published: 23-Dec-08

Abstract

The Electric Power Research Institute (EPRI) investigated the feasibility of phased array ultrasonic inspection techniques for detection of cracking in the keyway of large generator rotor shafts with shrunk-on couplings. The work was initiated after keyway cracking was discovered on two nuclear generator rotor shafts. The generator rotors had each developed high shaft vibration levels. The units were shut down to determine the source of the vibration. During disassembly, shaft cracking was discovered emanating from the shaft keyway area beneath the shrunk-on coupling. Removal of the coupling revealed the crack initiation point in the shaft keyway.

Objectives

Development of a phased array ultrasonic inspection technique for detection of generator rotor shaft keyway cracking is significant for at least two reasons. First, if the equipment owner has future plans to remove the rotor coupling to effect keyway inspection, the ultrasonic inspection technique can be used in the interim to provide an assessment of the keyway condition. Second, if the equipment owner chooses to not remove the rotor coupling for inspection purposes, the ultrasonic inspection technique is a reasonable alternative to assess keyway condition.

Approach

This inspection application investigation was funded as a supplemental project. EPRI has extensive experience with the development of phased array inspection techniques for a variety of electric utility applications. This experience, combined with effective modeling of the inspection application, supported the investigation.

Results

Development of a reliable phased array ultrasonic inspection technique for detection of generator rotor shaft keyway cracking eliminates the need to remove the generator coupling to facilitate keyway inspection using visual or surface inspection technique, as initially required by the original equipment manufacturer. Phased array ultrasonic inspection of the keyway can be performed with the rotor in situ, eliminating considerable resources that would otherwise be required to remove the generator rotor and then remove the generator rotor coupling to effect a visual or surface inspection of the keyway area.

Application, Value, and Use

The desire to extend service life of aging assets such as generator rotors requires careful assessment of component integrity. Effective monitoring of rotating equipment during operation as well as timely inspections can identify component degradation before catastrophic failure. Phased array ultrasonic inspection techniques can be used to detect keyway cracking in the early stages of development. Similarly, phased array ultrasonic inspection techniques can be a viable alternative to surface inspection techniques that require removal of the coupling for access to the keyway.

EPRI Perspective

Collaboration between EPRI and the electric utility industry facilitates development of unique solutions to industry challenges. The impetus for development of a phased array inspection technique for generator keyway cracking was the forced outage of two nuclear four-pole generators. Each generator had developed excessive vibration as a result of extensive torsional cracking emanating from the generator rotor keyway. Concerns about susceptibility of the generator rotor fleet to the keyway cracking phenomenon spurred development of an in situ inspection technique for reliable detection of keyway cracking. EPRI also possesses retired generator rotor segments for use as inspection mockups.

Keywords

Alternative inspection techniques
Generator rotor keyway cracking
Phased array ultrasonic inspection
Supplemental project

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001015256

EPRI Phased Array Performance Demonstration for Axial Entry Blade Attachment Inspection - Technical Update - 1015672

Product Type: Technical Update Date Published: 22-Dec-08

Abstract

The disk rim blade attachment area is one of the most highly stressed components of the steam turbine rotor. Reliable and accurate inspection of the disk rim blade attachment area is essential for the determination of rotor operability and remaining life. The purpose of the Electric Power Research Institute's (EPRI's) Phased Array Performance Demonstration for Axial Entry Blade Attachment Inspection Project is to determine the inspection performance levels of commercial entities offering these inspection services.

Objectives

Reliable and accurate inspection of the disk rim blade attachment area is essential for the determination of rotor operability and remaining life. This inspection information is useful in planning for maintenance activities and strategic run/repair/replace decisions related to low-pressure rotor remaining life. Documented inspection performance of commercial inspection companies on mockups with known flaw sizes is useful to electric utility personnel who purchase or oversee these inspection activities.

Approach

In 2008, EPRI invited known commercial providers of phased array inspections services for axial entry blade attachments to participate in a performance demonstration activity. EPRI mockups with manmade and service-induced flaws were used for the evaluation. The participants, WesDyne International and Structural Integrity Associates, collected and analyzed data from the mockups in 2008. The data were submitted to EPRI for correlation with known targets in the mockups. EPRI's analysis of the data and publication of a final report will be completed in 2009.

Results

The EPRI Phased Array Performance Demonstration for Axial Entry Blade Attachment Inspection Project is in the first year of a two-year project. During year one, EPRI developed mockups and demonstration protocols, solicited commercial inspection vendors to participate, and facilitated vendor data acquisition. During year two, EPRI will analyze vendor data, including flaw detection and sizing, and produce a final report summarizing test methodology and inspection performance results.

Application, Value, and Use

The desire to extend the service life of aging assets, such as steam turbine rotors, requires careful assessment of component remaining life. Similarly, off-design operation of rotors can consume useful service life of the component as compared to baseload operation. Documented, effective inspection techniques are essential for the accurate assessment of aging rotors.

EPRI Perspective

Phased array ultrasonic inspection technology has been applied to a wide variety of electric utility inspection applications. As proliferation of the technology continues, it is important for the inspection techniques to be vetted to determine flaw detection and sizing capabilities and to determine limitations of the inspection application. EPRI uniquely possesses a wide variety of component mockups suitable for these types of technique performance demonstrations.

Keywords

Low-pressure rotor
Phased array ultrasonic inspection
Steam turbine
Turbine blade attachment inspection

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001015672

Inspection and Damage Assessment of Turbine Casing Cracks - 1014138

Product Type: Technical Report Date Published: 31-Mar-08

Abstract

The average U.S. utility steam turbine is 40 years old. Continued operation of these units beyond their design life commands significant investment in maintenance, inspection, and repair activities. Steam turbine casings are prone to long-term degradation as a result of baseload operation. Casing degradation is exacerbated by the cyclic operation of these units. A variety of effective nondestructive examination techniques are available to detect and characterize turbine casing cracks. Effective crack repair techniques also exist and continue to evolve. Equally important to the utility is the ability to assess the criticality of turbine casing cracks and make strategic run/repair/retire decisions that support operational and financial needs.

Objectives

This report is useful for utility turbine engineers and others responsible for steam turbine operations and maintenance, inspection, life extension, and repair. Steam turbine casings are expensive, long lead-time components. Replacement of cracked steam turbine casings can, in many cases, be delayed. Casing life-assessment tools are available to predict remaining useful life of cracked casings. Proven weld-repair techniques are also available to extend casing service life.

Approach

Extensive background supplied in the report provides information on lessons learned regarding turbine casing cracking. Surveys of recent utility experiences with turbine casing cracking, inspection, assessment, and repair are useful in developing strategies for future occurrences of casing cracking.

Results

Past industry experience and surveys of recent utility experiences indicate that the steam turbine casing crack issue is manageable. Original equipment manufacturer (OEM) and non-OEM resources are available for the inspection, repair, and assessment of turbine casings. Relatively slow growth rates of casing cracks and the availability of effective damage assessment methodology allow utilities lead time to prepare for turbine casing repair or replacement.

Application, Value, and Use

Implementation of the inspection, life assessment, and repair methodologies described in this report will provide value in extended serviceability of steam turbine casings.

EPRI Perspective

Many of the U.S. steam turbine units are operating well beyond their original design life. This situation challenges utility engineers to maintain unit operability and availability. Effective component life-assessment tools and repair techniques are needed to extend the service life of these components. This report provides extensive background information related to the inspection and damage assessment of turbine casing cracks, OEM and utility experiences with a variety of casing repair techniques, and guidance for making the turbine casing run/repair/retire decision.

Keywords

Casing inspection
Nondestructive examination
Remaining life assessment
Steam turbine casing
Turbine casing repair
Weld repair

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014138

Boresonic Inspection Primer - 1014140

Product Type: Technical Report Date Published: 27-Mar-08

Abstract

Boresonic inspection systems provide flaw data that are essential inputs for rotor life assessment programs. Boresonic system technology has evolved from early manual inspection units using broad-beam inspection probes to computer-controlled systems with variable-focus probes and automated data collection. Boresonic inspection systems can identify inherent forging defects as well as flaws that have propagated in service. Evaluation of boresonic inspection systems identifies the flaw detection, sizing performance, and repeatability of these systems.

Background

The catastrophic failure of the Gallatin rotor in 1974 prompted U.S. utilities to conduct boresonic inspections of their rotor fleets to detect near-bore flaws in order to avoid future catastrophic failures. Early rotors were typically bored to remove the segregates and nonmetallic inclusions that congregated along the center axis as a result of the forging process. After a rotor is bored, the tangential stress resulting from centrifugal force is the greatest at its bore surface. Because of the stress concentration at the bore surface, it is essential to identify significant near-bore flaws in the forging. Inclusions can potentially link by a creep mechanism to form subsurface cracks lying near the bore. The cracks can propagate by a combined creep and fatigue mechanism until they reach critical size, and they can then lead to catastrophic rotor failure. A boresonic inspection is critical for detection of near-bore inclusions and cracks.

Objectives

- To provide information about the background, preparation, purpose, function, and evaluation of boresonic inspection systems that will be useful to personnel responsible for managing boresonic inspections

Approach

This report addresses various aspects of boresonic inspection, including the following:

- Industry events that led to increased rotor bore inspections
- Rotor failure mechanisms and their correlation with rotor bore flaws
- Inspection systems and their primary components
- Data analysis
- Inspection system evaluation program
- System evaluation history

Results

This report provides an overview of the key aspects of boresonic inspection and a list of references for further investigation.

EPRI Perspective

This report provides key information about boresonic inspection systems as they relate to rotor life assessment and avoidance of catastrophic failure. The catastrophic failure of the Gallatin rotor was an impetus to inspect the fleet of bored rotors. The evolution of boresonic inspection systems and rotor life assessment software programs has contributed to effective management of the rotor fleet.

Keywords

Boresonic inspection
Boresonic system performance
Nondestructive examination
Rotors
Ultrasonic inspection

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001014140

Plant Guide to Turbine Disk Rim Inspection - 1013459

Product Type: Technical Report Date Published: 18-Dec-06

Abstract

Steam turbine disk rims are one of the most highly stressed areas of the rotor. Periodic inspection of the rims provides information on the operability of the rotor, including the identification of conditions that could result in catastrophic failure of the rotor.

Objectives

Steam turbine disk rim cracking is a primary contributor affecting rotor reliability. Disk rim cracking is a result of localized stress, steam chemistry contaminants, temperature influences, operating conditions, and other contributors. Failure of the disk rim blade attachment area results in dislocation of turbine blades with the potential for catastrophic failure of the rotor. Periodic inspection of the turbine disk rim blade attachment area is essential for determining disk rim integrity and remaining component life. Several surface and volumetric nondestructive inspection methods can be applied to disk rims. The results of these inspections are used in the run/repair/replace decision process. Remaining life analysis software, specifically developed for disk rim evaluation, is also available in the industry.

Approach

The report provides guidance to utility staff who contract nondestructive inspection services for the highly stressed disk rim area. An overview of several surface and volumetric nondestructive inspection methods for two predominant disk blade attachment configurations is presented. Information is also provided regarding inspection personnel qualifications and inspection procedure review. Recommendations for the oversight of the inspection process are discussed for the purpose of achieving high-quality inspections and facilitating effective communication prior to, during, and at the conclusion of the inspection process.

Results

Effective nondestructive inspection of the turbine disk rim can be accomplished with volumetric and surface inspection techniques. A life assessment software code can be used to determine critical crack size in the disk rim area and provide remaining life assessment using a variety of material, stress, and operational factors.

Application, Value, and Use

As the domestic turbine fleet ages, incidences of stress corrosion cracking in the blade rim attachment area become more common. Periodic inspection of the disk rim and the use of life assessment tools can help utilities to more effectively plan maintenance and/or repair schedules.

EPRI Perspective

This report provides utility management and inspection personnel with information for steam turbine disk rim inspections. The report describes conventional and advanced nondestructive inspection techniques, information on inspection personnel training and qualifications, and other considerations for this inspection application.

Keywords

Blade attachment
Disk rim inspection
Nondestructive inspection
Steam turbine rotor

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013459

17
GENERATOR NON-DESTRUCTIVE EXAMINATION RESEARCH

Nondestructive Evaluation Methodology Applied to Turbine-Generator Components: Generator Retaining Rings - 3002003494

Product Type: Technical Update Date Published: 23-Dec-14

Abstract

Condition assessment and inspection of generator retaining rings is a complex process involving an array of different materials, numerous potential damage mechanisms, differing geometries, and the full range of available nondestructive evaluation (NDE) methods and techniques. Add to this the increasing demand and responsibility on utility staff, and it is easy to understand the need for a short, condensed guide presenting established EPRI research and an approach to selecting the appropriate NDE.

Background

Generator retaining rings—particularly those manufactured before the mid-1980s from nonmagnetic 8Mn5Cr material—are susceptible to corrosion attack in the presence of moisture. In view of this, original equipment manufacturers are recommending periodic in-service inspection or replacement of rings with stress corrosion–resistant material made of 18Mn18Cr material. Because of the high cost of ring replacement, utilities have chosen to continue to monitor rings for damage through the use of advanced NDE methods.

Objective

This report is intended to provide plant utility staff with a condensed guide that draws its information from established EPRI research and its application to specific turbine-generator components.

Approach

EPRI has prepared this report describing the care, inspection planning, and performance of generator retaining ring NDE examinations. NDE methods can be a valuable tool in determining the integrity of generator retaining rings. Also included in this report are short explanations of the appropriate NDE techniques and representative findings for various NDE methods. These findings are intended to be used be utility staff for evaluation of results provided by outside NDE suppliers.

Results

This NDE methodology guideline will provide plant staff with a concise “quick reference” on applicable NDE techniques along with references to published EPRI reports and workshop proceedings.

Applications, Value, and Use

This report on generator retaining ring examination is directed to plant personnel involved in the purchase, oversight, supervision, and review of outside NDE service provider results. Each NDE methodology guideline will address a specific turbine-generator component and is intended to be used as a quick reference for plant staff. Brief explanations of NDE techniques, their application, and representative examination findings of various types of damage are provided to educate staff who may not be exposed to advanced NDE on a regular basis.

Keywords

Nondestructive testing
Generator retaining-ring inspection
Generator retaining-ring damage
End rings
Retaining rings

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003494

Risk-Informed Inspection of 18Mn 18C Generator Retaining Rings - 3002003589

Product Type: Technical Report Date Published: 17-Nov-14

Abstract

Generator-rotor retaining rings, which rotate with the rotor and are typically made of nonmagnetic steel alloys, are the most highly stressed components in the entire turbine and generator-rotor system. Until the mid-1980s, an alloy containing 18% manganese and 5% chromium (18–5) was in worldwide use in generators. This alloy was susceptible to stress corrosion cracking (SCC) while operating in relatively mild environments, including exposure to moisture. In the mid-1980s, a new nonmagnetic alloy, containing 18% manganese and 18% chromium (18–18), was developed specifically to eliminate susceptibility to SCC damage. Since that time, retaining rings made of the 18–18 alloy have been successfully used in generators, with no known catastrophic failures and only rarely detected damage of any origin—including SCC. However, after 30 years of operating experience, some equipment manufacturers have now been recommending a comprehensive, time-based inspection program for all 18–18 rings in service. EPRI has therefore initiated a project to assess the operational history of the 18–18 alloy to determine if such an inspection program is justifiable and/or what levels of inspection and inspection approach would be appropriate and cost-effective. The primary objective of this project was to provide generator owner/operator recommendations regarding site-specific risks, based in part on responses to an industry-wide survey. No time-based generic issues for 18–18 retaining rings were found; all issues found resulted from specific events. The industry survey identified three event-driven damage mechanisms for 18–18 rings. The most prevalent mechanism is arcing damage between the ring and either the rotor or the amortisseur winding. Nearly half of the 10% of the total ring population that had some form of damage was attributed to arcing. The second damage mechanism is fretting, caused by relative motion between the retaining ring and the mating shrink-fit surface on the rotor. The stress source for fretting is frequent, high-load fluctuation leading to torsional oscillations. The third damage mechanism is stress corrosion and SCC. However, in contrast to the predecessor 18–5 alloy, the incidence for these types of damage for 18–18 alloy rings was very low (approximately 0.5%), and in all cases involved exposure to extremely aggressive environments not typically found in generators—specifically halogens (fluorine, chlorine, or bromine) and sulfur.

Keywords

Generator
Generator retaining rings
Generator retaining-ring inspection
Generator retaining-ring damage

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003589

Field Guide: Visual Inspection of Steam Turbine Generators - 1023848

Product Type: Technical Report Date Published: 14-Dec-12

Abstract

Mechanical failures of generator rotors and stators in fossil and nuclear power plants represent a loss of availability for power generation suppliers worldwide. Underlying condition issues and related problems can result in efficiency losses that restrict operation, cause reduction of maximum capacity, and create significant economic disadvantage. This field guide, part of a series of EPRI guides intended for practical use at power plants and in transmission and distribution settings, identifies condition problems that are typically found during the inspection of a steam turbine synchronous generator. The guide is organized into sections that cover basic knowledge, safety fundamentals, and each major component of the generator.

Keywords

Inspection
Maintenance
Steam turbine-generator
Synchronous generators

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001023848

Technical Basis for Generator Rotor Remaining Life Estimation Using Boresonic Inspection Data - 1025333

Product Type: Technical Report Date Published: 12-Dec-12

Abstract

Because they operate at much lower temperatures than turbine rotors, generator rotors do not experience the creep or thermal fatigue damage associated with turbine rotors. The major damage mechanism for generator rotors' near-bore regions is low-cycle fatigue due to startups. However, current practices of generator boresonic inspection do not differentiate between generator rotors and turbine rotors. The current practices also have large variations, ranging from no boresonic inspection to inspection every 10 years. The objective of this report is to provide a technical basis for generator rotor remaining life estimation using boresonic inspection data.

The Electric Power Research Institute's (EPRI's) Stress and Fracture Evaluation of Rotors (SAFER) software program was used to simulate near-bore crack growth and predict remaining life for six generator rotors. These six rotors covered a wide range of rotor geometries and manufacturing vintages. For each rotor, parametric studies of remaining life were conducted for multiple near-bore flaw sizes (small, medium, large, and extra-large); cycling operating conditions (base load, load following, and peaker); and rotating speeds (normal speed and overspeed). The simulation results of remaining life are summarized in a table for each rotor.

A screening tool is provided based on the parametric studies to estimate remaining life of generator rotors without the requirement of detailed SAFER analyses. It can be used to aid the setting of boresonic inspection intervals. Precautions need to be taken to avoid unconservative estimates of rotor remaining life by ensuring that all input parameters are within the applicable ranges. General conclusions are derived based on the parametric studies.

Keywords

Boresonic inspection interval
Generator rotor remaining life assessment
Rotor near-bore cracking
Stress and Fracture Evaluation of Rotors (SAFER) software

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001025333

Ultrasonic Inspection of Generator Rotor Dovetails with Limited Inspection Surface - 1014557

Product Type: Technical Update Date Published: 08-Nov-06

Abstract

Development of ultrasonic inspection techniques from the periphery of the rotor to detect circumferential/radial cracking on the wedge slot teeth crushing surface of large generator rotors began in 2003. A technical information letter (TIL) issued by the OEM identified the region as a potential problem and suggested a surface inspection technique be used on the crushing surface to detect cracking. That technique required the removal of the retaining rings and slot wedges prior to performing the inspection, an operation that is both time consuming and expensive. As a result of the TIL, EPRI funded a project to determine the feasibility of performing an ultrasonic inspection of the critical regions without the need to remove the retaining rings and slot wedges. Several ultrasonic techniques were investigated including the use of ultrasonic linear phased array technology. Ultimately this technology showed the most potential to reliably detect and size flaws deemed critical by the rotor manufacturer. The inspection could be performed from the rotor periphery, without the need to remove additional hardware, but rotor still needed to be removed from the stator.

Initial development was directed at rotors with smooth outer surface geometry, such as found on four-pole rotor designs, and rotors with lands and grooves that measure one-inch axial length, such as found on modern two-pole rotors designs. Rotors where the axial length of the lands and grooves were less than one-inch were not investigated at that time because of the emphasis placed on the more modern designs. The results of that study are documented in EPRI report 1008353, Investigation of an Ultrasonic Inspection Technique for Generator Rotor Dovetail Cracking, published in December 2004. The results of that development project clearly indicate that inspection from the outer diameter (OD) surface is not only feasible but a practical solution for detecting and sizing flaws on the wedge tooth crushing surface without removing retaining rings and slot wedges.

In 2005, EPRI was asked by a member utility to fund a study, with an abbreviated scope, and assess the feasibility of inspecting the earlier population of rotors with shorter lands and grooves. Initially, it was thought that these surfaces may be too limiting to develop an effective inspection approach. However, results of this recent study indicate that inspection is feasible although significantly affected by the limited surface area for probe placement and the physical dimensions of the lands and grooves.

Keywords

Dovetail
Generator
Ultrasonic Inspection

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001014557

Experience with Limited Access Generator Inspections: A Study of Inspections Done with Robotic Equipment and their Effectiveness as Compared with Conventional Inspections where the Generator Rotor is Removed - 1000100

Product Type: Technical Report Date Published: 08-Sep-00

Abstract

Limited Access Inspections (LAI) provide generator component assessment capability comparable and very often superior to conventional inspections with the rotor removed. This report studies actual inspections from two major OEMs and positively assesses their capabilities to perform inspections without removing the generator field rotor from the stator.

Background

Acceptance of LAIs by insurance companies as equivalent to rotor-out inspections is not universal. When this project is completed, EPRI will provide the insurance industry with a review copy of the findings and opinions of the final report. After reviewing that document, insurance companies will be better able to judge whether LAI inspections are equivalent to conventional inspections.

Objectives

- To document, substantiate, and gain insurance industry acceptance that LAI is comparable or superior to more traditional methods of internal generator inspections.

Approach

The data for this study was gathered from generator inspection reports at General Electric and Siemens-Westinghouse (S-W). Those reports covered the years 1995 through 1999. The project team reviewed a sample of 68 LAI reports to achieve this study's objectives. To get an overall impression of LAI's capabilities and site conditions, the team also reviewed video tapes of several units and typical site inspections. Particular emphasis was given to video images that were included in inspection reports. An opportunity also was made to witness a LAI and run through the various inspection procedures. The team also interviewed several general specialists who have performed LAIs to obtain subjective data. Many of the statements contained in this study and its conclusions include those data inputs. Two independent, third-party consultants served as the study's principal evaluators. This entire project is structured in two phases. This report is the first phase. The second phase will review this report's results with the insurance industry, identify any concerns, and document those issues in a follow-up report.

Results

Limited Access Inspections provide generator component assessment capability comparable and very often superior to conventional inspections with the rotor removed. This conclusion is based on evaluation of report data and conversations with other industry personnel (including utilities, industrials, OEMs, consultants, and generator specialists).

Based on a review of this study, suggestions to improve the quality of LAI and quantify its benefits include the following :

- Maintain and improve technical qualifications of generator specialists for LAI evaluations
- Create standards by which LAI visual inspections can be compared for consistency
- Consider vent-slot visual inspection capabilities
- Develop a photographic database of typical conditions for comparison
- Accumulate a database of actual costs to substantiate LAI economic benefits

EPRI Perspective

LAI should be considered as a universal substitute for rotor-out inspections. In addition to supplying standard tests and histories for maintenance and operations, LAI provides some of the essential ingredients for an overall comprehensive maintenance program. This report also indicates that LAI saves maintenance costs when compared to rotor-out inspections. The actual amount saved depends on an individual plant's situation and economics.

Keywords

Electric Generators
Inspection
Robotics
Robots

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001000100

18
GENERATOR EDUCATION TOPICS

Turbine-Generator Topics for Power Plant Engineers: Generator Synchronizing - 3002004970

Product Type: Technical Report Date Published: 23-Dec-15

Abstract

Synchronizing is the process of paralleling a synchronous generator to the bulk electrical system (BES). During startup, the turbine speed controls the generator frequency, and the generator excitation system controls the generator terminal voltage. When the generator's frequency and voltage are the same as that of the BES, a synchronizing system—either manual (via a control room operator) or automatic (via a relay or microprocessor)—must perform the following actions: 1) control the turbine governor to match the speed, 2) control the excitation system to match the voltage, 3) monitor the phase difference between the generator and the system, and 4) close the synchronizing breaker when the frequency, voltage, and phase are within defined limits.

This report explores the basics of generator synchronization, with emphasis on inspections and relevant Institute of Electrical and Electronics Engineers (IEEE) standards, particularly what to look for in the event of poor synchronization. The report will prove especially valuable in the training of control room operators, who must develop an understanding of the synchronization process. Such understanding is crucial to avoid out-of-phase synchronization that can cause a complete failure of the generator stator winding or the step-up transformer windings.

Keywords

Instrumentation and controls
Generator stators
Synchronous generators
Synchronization

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004970

Turbine-Generator Topics for Power Plant Engineers: Converting a Synchronous Generator for Operation as a Synchronous Condenser - 3002002902

Product Type: Update Date Published: 13-Mar-14

Abstract

Reactive load is constantly varying with transmission system load. Transformers and inductor motors draw current, which in turn causes voltage lag and impacts the transmission system as a whole. A synchronous condenser (SC) can compensate for system reactive changes and maintain the required system voltage set point by varying excitation or magnetic field strength of the SC's field winding, thus generating or absorbing reactive power. The SC can offset some of the reactive power changes required by inductive or capacitive system loads. Significant SC benefits include the fact that an SC produces no switching transients, remains unaffected by system electrical harmonics, and does not produce harmonics on the transmission grid.

This report highlights the technical issues associated with converting an existing shutdown or retired synchronous generator to operation as an SC. Beginning with the basic conversion process, the report documents the type of changes needed for major equipment components, suggested maintenance, and the expected reactive capability to be made available. Other issues discussed include controls that must be retained or added; required unit protection; unit interface to the grid, transformers, and other generation-related equipment; experience with utility SC conversions and other known conversion projects; cost of SC conversion; and various North American Electric Reliability Corporation (NERC) and regulatory issues. The intent of this report is to point out issues that must be addressed in order to achieve successful conversion of a synchronous generator to an SC, not to focus on one particular conversion scenario.

Keywords

Reactive load
Reactive power
Synchronous condenser
Synchronous generator
Synchronous generator conversion issues
Voltage lag

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002002902

Turbine-Generator Topics for Plant Engineers: Residual Magnetism - 3002001758

Product Type: Technical Report Date Published: 23-Aug-13

Abstract

The undesirable magnetization of components of rotating equipment used in the generation of electric power is a problem that has been recognized for many years; but wide understanding of the origins, detection techniques, remediation, and avoidance principles of residual magnetization has been lacking. As part of the series Turbine-Generator Topics for Plant Engineers, EPRI commissioned this report with the purpose of providing engineers active in the operation and maintenance of power plants with fundamental concepts on the problems related to undesirable magnetization phenomena due to residual magnetism in turbine generators.

This report describes the fundamental principles of the generation of residual magnetism and explains the differences between undesirable versus innocuous residual magnetism. It discusses the various sources of residual magnetism; what components can be negatively impacted; and the techniques available for the detection, control, and removal of residual magnetism.

The report presents a number of "good practices" that can minimize the establishment of residual magnetism where it is not supposed to be and illustrates these practices with case examples drawn from industry practice.

Keywords

Degaussing
Residual magnetism
Rotors
Turbine generators

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001758

Turbine-Generator Topics for Power Plant Engineers: Fundamentals of Electromagnetic Signature Analysis - 3002000102

Product Type: Technical Update Date Published: 15-Feb-13

Abstract

Electromagnetic signature analysis (EMSA) is the process used to evaluate the electromagnetic interference (EMI) generated by abnormalities in almost any energized power plant equipment—from cable connections to broken rotor bars in a motor to the isolated phase bus and generator step-up transformer. EMSA will detect any defect that involves EMI, noise, arcing, corona, partial discharge, gap discharge, sparking or microsparking, or any combination of these.

With EMSA, every signal has meaning. By monitoring all of the electrical activity from 30 kHz to 100 MHz, a great deal of information can be obtained. EMSA is most useful in comparing similar pieces of equipment for trending for predictive maintenance (PdM). Using EMSA, plant personnel can make informed PdM decisions while the equipment is still on-line.

This report describes plant equipment responses to a variety of defects across a range of frequencies. Guidance on using EMSA testing equipment and interpreting the results is provided. In addition, the use of EMSA in conjunction with other monitoring techniques is explored, and several case studies are presented that demonstrate actual EMSA applications.

Keywords

Condition monitoring and diagnostics
Electromagnetic interference (EMI)
Electromagnetic signature analysis (EMSA)

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000003002000102

Turbine-Generator Topics for Power Plant Engineers: Current Transformers and Voltage Transformers for Synchronous Generators - 1023497

Product Type: Technical Update Date Published: 05-Aug-11

Abstract

This technical update report is one of a series, Turbine-Generator Topics for Power Plant Engineers, intended for new engineers, control room operators, managers, and non-engineer personnel. This report describes basic transformation theory; types of instrument transformers, their purposes, and their characteristics; applications of transformers for synchronous generators, including operational and replacement issues; and maintenance considerations. It covers only single-phase transformers; three-phase transformers are not used for synchronous generators.

The current transformers used on generators are sometimes called bushing current transformers (because they are mounted over the generator's high-voltage bushings) or window-type current transformers. Voltage transformers are often called potential transformers. This report uses the terms current transformers and voltage transformers.

Keywords

Current transformer (CT)
Synchronous generator
Voltage transformer (VT)

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001023497

Turbine-Generator Topics for Power Plant Engineers: Motoring of a Synchronous Generator - 1022588

Product Type: Technical Update Date Published: 22-Feb-11

Abstract

This report describes the effects of motoring on the rotors of the turbine and the generator. The causes of damage and ways to protect against it are also addressed. The report offers recommendations for evaluating damage and inspecting the generator rotor as well as guidance on a protection scheme—including relays—dedicated to motoring protection. Finally, several actual motoring events are described along with their lessons learned.

Keywords

Generator rotors
Motoring
Relays
Synchronous generators
Turbine rotors

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001022588

Generator Stator Endwinding Vibration Guide: Tutorial - 1021774

Product Type: Technical Report Date Published: 19-Aug-11

Abstract

Electric generators have not changed much since their invention and yet today are being pushed to their limits in step with the rest of the plant equipment. As a result, depending on the design applications, the industry has experienced and continues to experience problems with various components of the generator, particularly the stator and stator windings. These are the subject of this tutorial. Such problems can be prevented and corrective action taken only with a proper understanding of the machine designs and the phenomena that affect them under both normal and abnormal conditions throughout the life of the machine.

This guide documents applicable electric generator principles so that the reader—presumably an owner or operator of one or more generators—can have a useful tool to make proper decisions for his or her equipment. The report describes the design of the machine, the forces, trends and problems, and the steps necessary to prevent or solve those problems. The following topics are covered: recommended maintenance and monitoring of operating parameters, stator construction, vibration phenomena, thermal phenomena, failure mechanisms, preventing failures, and repairing a stator after a failure.

Keywords

Electric Generators
Generator stators
Maintenance and repair
Stator windings

http://membercenter.epri.com/programs/056608/pages/productabstract.aspx?ProductId=000000000001021774

19

GENERATOR FAILURE INVESTIGATIONS

Retaining Ring Cracking at Wisconsin Electric Power Company's Port Washington Unit 1 -- Root Cause Analysis - 1007001

Product Type: Technical Report Date Published: 20-Jun-02

Abstract

This investigation indicated that the root cause of cracks found in a turbine-end generator retaining ring in Wisconsin Electric Power Company's Port Washington Power Plant was sub-synchronous torsional interaction.

Background

In April of 1998, Wisconsin Electric Power Company's (WEPCO's) Port Washington Power Plant (PWPP) station found significant cracks in the Unit 1 turbine-end retaining ring. The cracks were found during a ring inspection. Metallurgical examination of the 18Mn-18Cr rings indicated the cracks were due to fretting/fatigue rather than the intergranular stress corrosion cracking common in 18Mn-5Cr ring material. Fortunately, the cracks were detected prior to reaching critical crack length and catastrophic ring failure. Since the Unit 1 failure, the Unit 2, 3, and 4 rings have been inspected with no cracks observed. Due to the high risk to the generator posed by a failed retaining ring, a failure analysis was performed to determine the root cause of the unusual cracking.

Objectives

- To conduct a root cause analysis to determine the cause of cracking in the Wisconsin Electric Power Company's Port Washington Power Plant.

Approach

In work cosponsored by Wisconsin Electric Power Company, the project team conducted a metallurgical examination of the cracks in the Unit 1 turbine-end retaining ring and investigated the possible cause or causes of the failure. After identifying the most likely failure mechanism to be sub-synchronous torsional interaction, the team installed a torsional vibration data acquisition system to test and continuously monitor the plant for torsional vibration and line disturbances and monitored Units 1 and 3 during operation over a period of 8 months. At the end of the project, the team installed a permanent torsional vibration monitor.

Results

Metallurgical examination of the 18Mn-18Cr rings indicated the cracks were due to fretting/fatigue with growth on a 45-degree angle rather than intergranular stress corrosion cracking; the latter is more common in 18Mn-5Cr ring material. The probable root cause of the failure was sub-synchronous torsional interaction. This phenomenon, in which torsional vibration is excited at relatively low torsional frequencies, has not been previously reported for steel-mill/turbine-generator interaction. The phenomenon occurs under a specific set of steel mill-generating station operation conditions and is considered highly unusual, although a retaining ring failure at Unit 2 of Public Service of Colorado's Comanche Station did occur because of vibrations induced by power spikes from a local steel mill (EPRI report TM-106640).

EPRI Perspective

As a precaution, all four units of the Port Washington Power Plant are being monitored for torsional vibration.

Keywords

Failure Analysis
Fatigue Cracking
Retaining Rings
Root-Cause
Torsion
Vibration

http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001007001

20

STEAM TURBINE GENERATORS USED IN COMBINED-CYCLE APPLICATIONS

Operational and Control Strategies for Reducing Steam Turbine Damage from Cycling Combined Cycle Plants - 3002006026

Product Type: Technical Report Date Published: 21-Dec-15

Abstract

Combined cycle gas turbine (CCGT)–based power plants have, in many cases, seen a significant change in their operating profile over the past two decades. In many cases, plants that were originally designed for baseload- or hours-based operation are instead realizing operating profiles that experience high starts, lower than expected capacity factors, and a significant amount of load following throughout the course of the day. Over the years, there has been a great deal of effort by original equipment manufacturers (OEMs) and owners alike to investigate and evaluate methods to improve the operational flexibility of the CCGT facilities, including enhanced turndown capability, increase ramp rates, all in order to improve their market presence. Much of this work has been focused on the combustion turbine generator (CTG) side of the facility, with little thought to how these changes might affect the steam side of the facility, with particular emphasis on the steam turbine generator (STG). The report has, through a series of interviews and site visits, investigated the impact of increased cycling on the STG.

Background

CTG OEMs are often, but not always, the STG OEMs at any given plant. Many STG OEMs have claimed that during the design phase their STGs have been specifically designed for use in CCGT facilities and that they have been specifically designed for the cycling requirements. These units tend to be smaller and lighter than their utility predecessors in order to facilitate faster starting times due to shorter warm up timers. However, as plants have started cycling more and more, very little regard has been given to what shorter start times, lower turndowns, and other modifications to the gas turbine side of the plant may have on the steam side.

Objectives

The research conducted during this study sought to identify industry best practices used by operators to mitigate and minimize damage to the steam side of CCGT power plants, especially the steam turbine.

Approach

The research conducted for this study involved conducting phone interviews with plant staff at nearly 50 CCGT power facilities worldwide, including the United States, Japan, England, and Italy. Survey questions included site-specific configurations, operational profile and dispatch data, and steam side maintenance histories. Based on the results of these initial interviews, a total of four sites were selected, sites that were doing something unique or that was deemed to be industry leading or perhaps sites that had experienced unique problems, for follow-up on-site visits. These visits lasted from one to two days in duration and were specifically meant to witness a startup and shutdown cycle. However, since these cycles are often at the discretion of regional dispatching authorities, in several instances it was not possible to actually be present during a startup/shutdown. During the site visits, additional time was spent evaluating what each site did that was unique and what set them apart from their counterparts and how their processes and procedures were implemented and used.

Results

It was interesting to note that, by and large, many of the sites that participated in the study reported minimal direct impact on the STG as a result of cycling. However, when questioned further, many admitted that their units have been affected by cycling and many had experienced damage to heat recovery steam generators, steam attemperators, generators, control valves, and, of course, the steam turbines themselves. Damage ranged from minor maintenance issues, such as attemperator controls, to more significant issues, such as steam turbine blade erosion, to major issues, such as water ingress in the STG leading to significant bowed rotors, requiring extensive outages to repair. Few sites claimed that some damage may not have been caused directly by cycling, but may have been exacerbated by cycling.

Applications, Value, and Use

The contents of this report will be of use to CCGT plant operators, owners as well as developers as they try to plan for long-term maintenance of their steam turbine.

Keywords
Steam turbine
Cycling
Generator
Attemperator
Control valves
HP steam
LP steam

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006026

Maintenance Guidelines for Generators Used in Simple and Combined Cycle Plants - 3002003590

Product Type: Technical Report Date Published: 17-Dec-14

Abstract

Gas-fired combustion turbine plants, which were originally designed for base load operation, are now operated primarily in two-shift cycling mode. Cycling has the effect of accelerating aging factors for generator components. Generators that have been forced to adapt to a cycling mode of operation may require major maintenance, including rewinding or replacement of rotors and stators. This report provides maintenance guidelines for air and hydrogen cooled generators supplied by major US, European, and Asian generator original equipment manufacturers (OEMs) and their licensees, operating in 50 and 60 Hz systems, in single and combined cycle gas fired combustion turbine power plants.

The report identifies components that need to be monitored, inspected, repaired, and replaced over the lifetime of a plant and discusses the timing and duration of maintenance activities. It describes the failure mechanisms of stator cores, stator windings, and rotor mechanisms and covers generator access and handling issues related to removal, lifting, lay-down, and transportation at typical configurations of single and combined cycle plants combustion turbine plants.

Keywords

Maintenance
Combined Cycle
Failure mechanisms
Combustion turbines
Generators

https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003590

Steam Turbines and Generators in Combined-Cycle Applications: Design Characteristics and Reliability - 3002003866

Product Type: Technical Report Date Published: 26-Nov-14

Abstract

Combined-cycle power plants are the preferred technology for new power generation capacity in much of the world, particularly in the United States. Steam turbines and electrical generators are vital components affecting combined-cycle plant performance and reliability. Most of the world's combined-cycle steam turbines are provided by five major manufacturers: Alstom, General Electric, Mitsubishi Hitachi Power Systems, Siemens, and Toshiba. This report provides information on their model offerings and considerations for reliability and procurement.

Results and Findings

This report contains the results of two principal areas of study: (1) a concise presentation of the design characteristics of steam turbines and generators from five major manufacturers and (2) an analysis of reliability statistics for steam turbine and generator systems. Installation lists for large steam turbines from the major manufacturers are also included. Developments in steam turbines have been focused on improving efficiency and flexibility. Current steam turbines and generators in combined-cycle service have very high levels of reliability and availability. However, not only are they subject to the same areas of concern and damage mechanisms as steam turbines in conventional fossil steam applications, but they also are subject to conditions unique to combined-cycle applications, such as faster cycling and higher relative steam volumes in the low-pressure section. Current steam turbine offerings incorporate the latest three-dimensional blade profiles and seal technology for improved stage efficiency, longer last stage blades for higher capacity without additional low pressure casings, and designs that accept higher steam pressures and temperatures for improved steam cycle efficiency.

Challenges and Objectives

Developers of combined-cycle power plants must select a steam turbine manufacturer during preliminary design and procurement phases of the project. Although steam turbines and generators are generally mature technologies, project developers and associated engineering firms should understand design offerings and options provided by manufacturers, particularly those involving more advanced technologies and operating conditions. The objectives of this report are twofold: (1) to provide information regarding design and options for steam turbines and generators during the selection and procurement process that can affect durability and reliability of the machine and (2) to assess the reliability of steam turbines based on statistical information and provide insights from that analysis.

Applications, Values and Use

This report is intended for use in the preliminary design and procurement phases of project development as a reference guide for engineers and power project developers responsible for the steam turbine and generator selection process. It describes steam turbines from about 100 MW to over 500 MW in capacity. The table of design characteristics for five major manufacturers provides fundamental information for use during selection. The reliability statistics and their interpretation provide a sound basis for reliability and availability expectations and an indication of the top causes for unplanned outages.

The engineer/developer of combined-cycle plants should have a fundamental understanding of the design attributes of the major equipment and the impact that certain options and decisions may have on equipment durability, reliability, performance, and maintenance costs over the life of the project. While most of the attention during project development is placed on the combustion turbine, other balance-of-plant equipment - including the steam turbine and HRSG - should not be neglected. With natural gas supplies projected to be readily available into the foreseeable future, combined-cycle plants are the preferred option for new, fossil generation and as backup for new renewable capacity. Steam turbines provide over one third of the generation from combined cycle plants and play an important role in the power island.

Approach

The project team reviewed the configuration options and design characteristics of five major steam turbine manufacturers and prepared tables describing those attributes in a common format. The team described areas of technical risk for steam turbines and electrical generators and compiled reliability data from steam turbines in combined-cycle service.

Keywords

Design
Reliability
Procurement
Steam turbine
Combined Cycle
Generator

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Generators in Combustion Turbine (CT) Applications: Failure Mechanisms - 3002000441

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Abstract

As combustion turbines (CTs) come into wider and wider use to provide peaking power and supplement intermittent renewable resources, operating experience indicates that competitive pressures and reduced design margins have resulted in some generic problems that affect the reliability of generators and limit their life expectancy. While some users have entered in long-term service agreements with original equipment manufacturers (OEMs) to look after the predictive and corrective maintenance of their units, others depend on their own resources to recognize emerging problems and manage their correction with the help of available service providers. Because plant personnel often lack specialized knowledge and familiarity of generator design and failure mechanisms, the need has been expressed for an overview of generator design and a basic description of generator failure mechanisms. The objective of this report is to present information on generator design and operating issues for staff at CT power plants.

The report provides a brief description of generator design followed by a discussion of a range of operating issues and failure mechanisms (FM) that may develop in service and affect unit reliability. The description of the FMs include a short description of each FM and its possible consequences, information the operator needs to recognize the FM and take a possible action, and a short list of possible ways to avoid the repetition of the FM in the future. The report will be updated regularly as new information becomes available.

Keywords

Combustion turbines
Failure mechanisms
Maintenance

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com