Steam Turbines-Generators and Auxiliary Systems - Program 65

Program Overview

Program Description

A majority of outages planned at coal, nuclear, and combined-cycle power plants involve maintenance tasks performed on turbines and generators. Owners of aging turbine-generator fleets continually seek ways to optimize operation, maintenance, and outage activities through improved condition assessment, risk-informed task prioritization, and inspection/repair procedures.

The Electric Power Research Institute's Steam Turbines-Generators and Auxiliary Systems Program (Program 65) supports continuous improvement in the safety and availability of steam turbines, generators, and auxiliary systems. It supports all aspects of turbine-generator component life cycle management, including evaluation and procurement of system upgrades. This support is accomplished through applied research in component life management, preventive maintenance, condition assessment, and controls.

The program also fosters collaboration among all industry stakeholders to support proactive strategies and best-practice sharing to solve industry issues. The ongoing research and technology transfer activities fully support the needs of member organizations seeking to improve knowledge and effectiveness of new turbine-generator system engineers.

Research Value

Using an integrated approach that incorporates work from related EPRI programs, this program focuses on reducing operations and maintenance (O&M) costs, managing risk, maximizing plant performance, providing technical support for plant staff, and producing information to support upgrade studies and asset management strategies. Research results inform decisions regarding run/repair/replace and provide detailed guidance for planning and performing critical overhaul and maintenance activities.

By participating in this program, plant operators obtain information that they can use to:

- Reduce maintenance costs
- Maintain high asset availability
- Take proactive measures to lower operating and regulatory risks
- Implement cost-effective thermal performance improvements
- Extend component life
- Increase staff technical expertise and awareness of industry issues

Involvement in the program will help:

- Educate participants about worldwide turbine-generator (T-G) issues and solutions
- Provide opportunities to share information with industry experts, engineers, major T-G original equipment manufacturers (OEMs), and vendor/service providers worldwide

Approach

This program produces a range of deliverables including published guidelines, software, databases, and technical meetings/webcasts. Specific project selection is based on periodic advisor input and issue ranking. The portfolio addresses current areas of need such as flexible operations, component upgrades, condition monitoring technologies, preventive maintenance (PM) guides, component inspections, and repair strategies. Project advisory groups are involved in project scope creation, draft report review, and sharing of research implementation best-practices. The Turbine-Generator Users Group provides program members an effective forum for sharing research implementation experiences, as well as guiding further EPRI research in key areas. In addition, program members have access to recorded technical webcasts, an annual newsletter, and past

research catalogs. These products allow members to easily disseminate the latest knowledge to key staff at the main office and plants.

Many members begin their participation in Program 65 research through regular participation in the EPRI Turbine Generator Users Group (TGUG) biannual meetings. These are member-run forums for sharing technical knowledge, awareness of emerging reliability issues, and O&M best-practices among turbine-generator system engineers. The group also provides a structured forum for engaging the six major turbine-generator equipment manufacturers worldwide. Program members also are eligible to attend the workshops associated with the biannual group meetings.

Potential projects for the following year's R&D portfolio are discussed and prioritized with the program member advisors during the two Program Advisory meetings held twice yearly. Roundtable discussions held at the Advisory meetings, as well as the TGUG, provide opportunities, as appropriate, for EPRI's collaborative R&D to immediately address emerging issues that broadly affect the industry.

Accomplishments

EPRI's Program 65 is recognized in the power industry as an authoritative source for up-to-date information on turbine-generator issues and solutions. Several documents, many updated periodically, have become guiding resources for the industry. These resources are becoming increasingly important to train and educate new staff at the plants and main office. EPRI has created a successful process for continual dialogue among all industry stakeholders, including commercial suppliers, that focuses on key technical issues and resolutions. Some key specific accomplishments of the program include:

- Annual updates to the *Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections*
- Release of maintenance guides covering seven key turbine-generator auxiliary systems
- Series of reports covering emerging technology and procedures for assessing the health of generator windings
- Guidelines for maintaining generator stator water cooling systems
- Tutorials and workshops to improve technical understanding of key industry issues such as torsional vibration
- Comprehensive guidelines for troubleshooting turbine steam path damage, published in detailed reports as well as handbook formats
- Turbine-generator equipment and component repair and purchase specifications
- North American Electric Reliability Corporation (NERC) regulation education and generator capability validation assistance
- Turbine-generator component nondestructive evaluation (NDE) testing and application guidance
- Turbine steam path thermal performance modeling software
- Successful format for regular interaction with all major turbine and generator OEMs worldwide

A downloadable, comprehensive list of more than 140 current project deliverables from Program 65 is available at www.epri.com under document ID 1025031.

Current Year Activities

The program R&D for 2013 will focus on operation and maintenance costs reduction, unit and component risk management, turbine thermal performance, and the education of utility plant staff through workshops, seminars, and webcasts. Specific efforts will include:

- Update to generator stator water cooling system operations and maintenance guide to address current issues with plugging
- Identification of issues with new lower minimum load operation of turbines and generators
- Research on issues specific to large air-cooled generators
- Weld repair guidelines for steam valve chests and turbine casings

- New technology and strategies for turbine overspeed protection
- Technology to assist in passive testing and monitoring of turbine-generator shaft torsional mode frequencies
- Assessment of capabilities for ultrasonic inspection of curved axial-entry blade roots
- Technical basis for generator end-winding vibration limits

Estimated 2013 Program Funding

$6.0M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P65.001	Operations and Maintenance Cost Reduction	This project develops guideline documents for condition assessments, outage planning, replacements, disposition of damaged components, repair techniques, corrective actions, and specific maintenance practices for turbine generators and their auxiliary systems.
P65.002	Risk Assessment	This project provides emerging technologies for turbine-generator inspections, condition monitoring, and component failure risk assessments. Risk quantification can be combined with maintenance and replacement power costs to assess financial risk.
P65.003	Information Exchange for Plant Staff	Participation in this project's annual workshops and meetings allows utility personnel to be more proactive in managing risk and employing the most appropriate repair techniques. Participants can become more aware of current industry experiences and best practices in improving the reliability and availability of turbines and generators

P65.001 Operations and Maintenance Cost Reduction (052070)

Key Research Question

Repair guidelines are used to plan and execute major outage activities, resulting in less emergent work, on-schedule completion, and reduced risk of startup delays.

Approach

This project addresses core issues facing engineers responsible for turbine generator systems — reducing O&M costs through effective maintenance planning and execution by:

- Developing continually updated guidelines to assist in outage planning, disposition of damaged components, repair techniques, corrective actions, and specific maintenance practices
- Analyzing the impacts of flexible operation and unit upgrades and uprates
- Producing preventive maintenance (PM) data tables to guide optimization strategies
- Optimizing generator rotor maintenance, exciter maintenance, and retrofit and replacement guidance

Impact

- Decrease outage duration
- Increase outage intervals
- Reduce emergent work
- Optimize major component replacement timing
- Improve repair of components
- Utilize new materials as solutions to specific component degradation issues
- Improve thermal efficiency
- Improve turbine-generator preventive/predictive maintenance process and practices

How to Apply Results

The documents and preventive maintenance data tables produced by this program can be used to support equipment repair or testing or component condition assessment tasks. EPRI members can integrate the content in these guidelines directly into their own corporate procedures and training materials. The guidelines can be placed on internal networks and provide an excellent resource for continuous improvement training, as well as new-hire orientation for system owners and maintenance staff. Member companies planning new equipment purchases can take advantage of this project's results to prepare their own site-specific procurement specifications.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections-2013: Outage planning and execution information will continue to be added to the seven volumes of information (as identified by the utility project advisory group), which has been collected over the past 12 years in this product. Further improvements, as needed, to the electronic format of the Guidelines project also will be included in the year's activities.	12/31/13	Software
Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections-2013: Supplemental Additions: The specific 2013 outage planning and execution information added to the individual Guidelines project volumes will be collated in a supplemental technical update and offered on EPRI's web site as a downloadable document.	12/31/13	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Turbine-Generator Auxiliary Systems, Volume 4: Generator Stator Cooling System: 2013 Update: Turbine Generator Auxiliary System Maintenance Guide Volume 4: Generator Stator Cooling System (1015669) was published in 2008. The objective of the update is to include worldwide experiences with maintaining proper water chemistry, root causes, and lessons learned from units that experienced stator cooling water flow restriction.	12/31/13	Technical Report
Impact of Reduced Minimum Load Operation on Turbines and Generators: Coal plants are seeking lower minimum loads in order to remain viable for dispatch during daily high-demand periods. This project will identify the main considerations in frequent operation at low load for both the steam turbine and generator. Failure modes, effects, and damage mitigation strategies will be covered.	12/31/13	Technical Report
Air-Cooled Generator Failure Mechanisms: Continuing with the series of Program 65 Field Guides, which are a proven, useful tool for failure identification and mitigation, EPRI will produce a field guide focused on the air-cooled subset of electric generators. This will focus on the issues unique to this class of equipment and provide a tool to increase reliability.	12/31/13	Technical Report
Turbine Casing and Valve Chest Cracking Repair Guide: This guide will include a brief introduction to the materials (metallurgy and weldability concerns); brief information on defect detection methods; material removal methods; welding and mechanical repair methods; and guidance regarding permanent vs. temporary repair concerns. Information included in this guide will come from previous EPRI reports, discussions with industry, conference proceedings in 2012, literature reviews, member survey(s), and on-site meetings conducted to observe, understand, and document current state-of-the-art repair techniques utilized in the industry.	12/31/13	Technical Report
Electromagnetic Signature Analysis Software Version 2.0: The software "Electromagnetic Signature Analysis (EMSA) Software version 1.1" (Product 1022501) was developed for predicting the frequency response of large utility generators. This project will provide additional features that will improve EMSA interpretation. The improvements consist of capturing electromagnetic signature measurements and improved sharing of information among users of the software.	12/31/13	Software

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Electrohydraulic Control (EHC) Fluid Maintenance Guide: 2014 Update: This project will update the current EPRI EHC Maintenance Guide with new information. Additionally, because cycling of baseload units has become an economic reality for the industry, proper layup of auxiliary systems needs to be established. This revision will include a component on proper layup of the EHC system with a focus on maintaining fluid integrity upon restart.	06/30/14	Technical Report
International Steam Turbine Valve Actuator Maintenance Guide: This project will add international design turbine steam valve actuator models to the domestic U.S. designs already included in the 2008 release of the maintenance guide. The document will cover the disassembly inspection, component inspection, and actuator reassembly.	06/30/14	Technical Report

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections-2014: Outage planning and execution information will continue to be added to the seven volumes of information (as identified by the utility project advisory group), which has been collected over the last 13 years in this product. Further improvements, as needed, to the electronic format of the Guidelines project also will be included in the year's activities.	12/31/14	Software
Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections-2014: Supplemental Additions: The specific 2014 outage planning and execution information added to the individual Guidelines project volumes will be collated into a supplemental technical update and offered on EPRI's web site as a downloadable document.	12/31/14	Technical Update
Steam Turbine Exhaust Hood Spray Performance Optimization: Increased turbine operation at lower minimum loads increases the use of exhaust hood sprays used to cool the hood due to windage heating. Research will explore the effectiveness of current hood spray system design and operation in achieving the objectives of hood cooling with minimum risk to turbine components. New exhaust cooling schemes will be proposed for future field testing.	12/31/14	Technical Report
Life-Cycle Management of Air-Cooled Generators: Modern air-cooled generators were designed with high material utilization and put in service in plants with low capacity factor. Some designs, such as global vacuum-pressure impregnated stators, have developed insulation problems; others have been plagued with problems related to end-winding vibration. Almost all air-cooled generators now are operating all the time because of the availability of inexpensive natural gas. EPRI has produced a series of "Life-Cycle Management Planning Sourcebooks," each containing a compilation of industry experience and data on aging degradation and historical performance for a specific type of components. The objective of this project is to provide information and guidance for implementing cost-effective life-cycle management (LCM) planning for air-cooled generators operating in simple- and combined-cycle plants.	12/31/14	Technical Report
Field Verification of Benefits of Filming Amines on Steam Turbine Corrosion Protection: Filming amines added to the feedwater have been shown to provide protection to the boiler-turbine circuit during unit layup. This project will explore these benefits in detail by experimentally determining the effects on a side stream of low-pressure flow in a commercial power plant. The EPRI converging-diverging nozzle will be employed to simulate the phase-transition zone, using coupons of blade and disk material to assess pitting characteristics. Comparative testing, both with and without use of amines, will be conducted.	12/31/15	Technical Report
Condition Assessment of Rotor Journals Following Loss of Lubrication Event: Lubrication of rotating machinery is critical to proper equipment operation, and loss of oil film can result in significant amounts of damage. Once this happens, proper assessment of the journal condition is important so that effective yet economical steps are taken to repair and return the machine to service. This report will provide the plant personnel with a procedure to establish the condition of journals after a loss-of-lubrication event.	12/31/15	Technical Report
Technologies to Reduce Cost of Compliance with NERC Standards MOD 024-027 and PRC-024: North American Reliability Corporation (NERC) standards MOD-024 Real Power Capability Verification, MOD-025 Reactive Power Capability Verification, MOD-026 Excitation Response Verification, MOD-027 Frequency Response Verification, PRC-024 Frequency and Voltage Excursion Ride-Through Performance require periodic (5-,10-year. or following	12/31/15	Technical Report

Product Title & Description	Planned Completion Date	Product Type
equipment replacement/modification) verification. The generator owner is responsible for the model parameters and determining if the validated fit is "good enough." For new installations, PRC-024 will require defined voltage and frequency ride-throughs. Verification can be achieved by staged test at significant cost or ambient monitoring at reduced cost. The objective of this project is to identify and develop other cost-reduction technologies.		

P65.002 Risk Assessment (052072)

Key Research Question

Risk assessment is an important aspect of short- and long-term asset management. This requires a combination of component inspection techniques, on-line monitoring tools, results interpretation techniques, analytical tools to remaining life, and corrosion degradation modeling.

Approach

This project provides and demonstrates emerging technologies for addressing:

- Turbine-generator condition monitoring and results interpretation techniques
- Tools for performing component failure risk assessment
- NDE and remaining-life assessment of turbine-generator components
- Material corrosion/erosion prediction
- Guidelines for component root-cause analysis

Impact

- Accurate assessment of risk carried by turbine-generator systems
- Guidance in run/repair/replace decisions, life-cycle management, and overall optimal use of capital resources
- Information on emerging technologies for assessing turbine-generator condition and component failure risk

How to Apply Results

The EPRI technologies produced by this program can enhance the ability to analyze and quantify the current and future risks associated with component failure, replacement, upgrades, and uprates. Members can use the information from this project as an independent guide to effectiveness of various technologies and practices available to the industry to manage risk. Examples include access to component inspection mockups that allow members to more confidently evaluate nondestructive inspection systems and personnel, and documented field applications of emerging component monitoring tools and techniques.

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Turbine-Generator Overspeed Protection: Technology and Strategies: This project will establish the technical basis for turbine overspeed protection systems, considering nuclear versus fossil differences. The research also will explore the advantages and disadvantages of new technology for preventing overspeed events. Finally, the report will include results of an assessment of industry best practices relative to use of new electronic overspeed systems.	12/31/13	Technical Report

Product Title & Description	Planned Completion Date	Product Type
Use of Advance Pattern Recognition to Monitor Health of Stator Water Cooling Systems: This project will demonstrate and document the use of advanced pattern recognition models applied to generator parameters (load, water temperature at each bar outlet and slot RTD, cold water and hydrogen temperature, water cooling flow, delta P across filter/strainer, dissolved oxygen content, and electrochemical corrosion potential [ECP]) for early detection of stator water cooling flow restrictions.	12/31/13	Technical Report
New Technology for Monitoring Turbine-Generator Torsional Vibration: Turbine-generator shaft torsional vibration continues to create risk of component failures and costly consequences for plant operators procuring replacement rotating components. Predictive modeling during the retrofit design process can estimate rotor vibrational characteristics, but the calculation uncertainty often can result in a requirement to install torsional monitoring equipment to verify natural frequencies and identify potentially damaging torsional grid events. This project will investigate new technology for monitoring shaft torsional vibration characteristics that can be employed with minimum impact on plant operation, and can offer sufficient sensitivity and frequency resolution to identify all modes of interest. The project will identify existing sensor and wireless data transmission elements that can be combined to fit this application.	12/31/13	Technical Report
Technical Basis for Generator End Winding Vibration Alarm Limits: End winding vibration displacement/ acceleration alone are not sufficient to make operating/maintenance decisions. The vibration limits depend on design (flexible, rigid, length of overhangs), type of cooling, type of blocking/banding, the age, and the history of the winding. It may be possible to discriminate between a healthy winding and a deteriorating winding by looking at the full frequency spectrum of the vibration response. The objective of the project is to identify key parameters for condition assessment of the end winding.	12/31/13	Technical Report
Axial-Entry Blade Root Nondestructive Examination: Fatigue cracks in large low-pressure steam turbine blade root attachments remain a major source of operational risk for plant operators. The increasing size and mass of retrofit blades used in nuclear turbines, combined-cycle plants, and coal plants results in the need for greater attention to component condition assessment. Axial entry fir-tree root designs require periodic ultrasonic (UT) inspections to verify absence of fatigue cracks at the high-stressed fillet radii of the hooks. This project will examine the capabilities of current phased-array UT to fully detect and size cracks in a range of fir-tree root designs. Parameters that affect feasibility of commercial field inspections will be the focus of this research.	12/31/13	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Numeric Modeling of Blade Aeroelastic Stability: Current Capabilities and Research Needs: Aeroelastic vibration of final-stage low-pressure steam turbines, often referred to as blade flutter, is of increasing concern to plant operators due to the larger blades being installed and the increased risk associated with high backpressure operation. The analytical prediction of flutter during the design of specific blade airfoils remains extremely challenging because it requires a tightly coupled model that includes both the blade structural characteristics as well as the surrounding aerodynamics. This project will research the current state-of-art for axial flow turbomachinery blade stability calculations, and determine their suitability for application to the specific needs of modern steam turbine blades.	12/31/14	Technical Report

Use of Advanced Pattern Recognition to Monitor Health of Generator Collector Brush Problems: This project will demonstrate and document the use of advanced pattern recognition models applied to field voltage and current for early detection of collector brush problems.	12/31/14	Technical Report
Use of DC Ramp Test as a Diagnostic Tool: Technology Assessment and Interpretation: The information on winding condition available from a high direct-voltage test can be considerably enhanced by observing the variation of current (or insulation resistance) as the test voltage is gradually increased. If a weakness exists in the groundwall, and if ambient conditions are right, breakdown often is preceded by a sudden, nonlinear increase of current (or drop in insulation resistance) with further voltage increase. This enables an experienced operator to interrupt the test at the first sign of such warning, and if the voltage withstand already achieved is considered sufficient, to return the machine to service until such time as repairs may conveniently be scheduled. The record of voltage versus current taken during the test can be used in future comparisons on the same winding, provided that the same test conditions exist. The objectives of the project are to provide practical guidance how to use the DC ramp test results for condition assessment.	12/31/14	Technical Report
Experience with Digital Automatic Voltage Regulators and Generator Protection: Digital controls, protection, monitoring, and communications play important roles in plant operation and grid support. The objective of this report is to collect lessons learned from control and protection retrofits and to identify smart grid technologies that could be applied in power plants.	12/31/14	Technical Report
Technical Basis for Assessing Risk of Bearing Failure Following Loss of LP Blading: The loss of a last-stage blade will result in machine imbalance that can cause significant damage to bearings, possibly causing failure of this component of the support system. This report will establish a technical basis for assessing the overall risk to the bearings in the event of a loss of a last-stage blade, allowing companies to properly determine their exposure and evaluate this with respect to their risk tolerance	12/31/15	Technical Report
Guidelines for Turbine-Generator Risk Assessment Program Strategy and Technology Options: Power plant insurers increasingly are focused on risk associated with major failures of the steam turbine and generator. Risk areas include failure of blades, overspeed controls, shafts and disks, generator windings and core, and shaft torsional vibration. A programmatic approach to managing risk will be needed as the insurers adopt a more systematic risk evaluation process. This project will address turbine-generator risk assessment from a high-level, programmatic perspective. The project focus will be on employing the latest technologies for risk assessment and mitigation.	12/31/15	Technical Report
Abnormal Negative Sequence Analysis Excel Application Version 2: With increasing demand on the electrical grid, plants need to be aware of the interaction of the grid with turbine generators. Unsymmetrical electrical faults in the transmission system, such as a stuck circuit breaker pole, can cause the generator rotor surface to overheat. In 2010, EPRI developed an MS Excel® program (1017492) to quickly assess the risk of allowing the rotor to operate safely after exposure to large negative sequence. The objective of the project is to extend the software to condition assessment following accidental energizing of the generator from standstill.	12/31/15	Software

P65.003 Information Exchange for Plant Staff (052076)

Key Research Question

Application of EPRI research results by member plant staff is made difficult by decreased staffing levels and loss of expertise through retirement. New employees need effective information and peer-sharing opportunities that provide faster, more efficient knowledge delivery in areas of plant equipment operation and maintenance issues.

Approach

The program has developed a series of workshops and user group meetings held at regular intervals of 6 to 24 months. Each meeting has specific objectives and has evolved with strong member guidance to be highly effective as an information exchange forum. Structured roundtable discussions involving more than 100 attendees identify and clarify emerging issues. Opportunities to obtain the equipment supplier perspective in the same forum reduce the time required to drive to a solution. Depending on the disposition of each issue, additional R&D may be needed and is noted for future EPRI research portfolio development. The Turbine-Generator User Group (TGUG) was started in 2000 with a focus on domestic U.S. power producers, but recently has expanded to include meetings in Australia and Europe.

Additional activities that promote information exchange include an annual turbine generator failure report, industry newsletter, past research catalog, recorded technical webcasts, and a biennial Technology Transfer workshop.

Impact

- Increased turbine-generator staff awareness of emerging issues and successful strategies for resolution
- Application of lessons learned from peer companies
- Effective dialogue with a range of equipment and service providers, focused on technical issues

How to Apply Results

Active participation in the Turbine Generator User Group and attendance at the workshops, conferences, and technical webcasts will aid members in applying the results from Program 65. These results are delivered in the form of services, meeting notes, and web-based information with a focus on current industry information relating to steam turbine generator reliability, failure mechanisms, corrective action, and equipment supplier guidance.

Several opportunities are offered to attend EPRI-sponsored events to share lessons learned with other utilities and stay abreast of technologies, including:

- EPRI Turbine-Generator Technology Transfer Workshop and Steam Turbine Generator Workshop and Vendor Exposition
- Biannual USA Turbine-Generator Users Group meetings and January workshop
- International Turbine-Generator Users Group meetings in Europe and Australia
- Technical webcasts offered to domestic and international members, scheduled appropriate to their time zones

2013 Products

Product Title & Description	Planned Completion Date	Product Type
Two Turbine Generator User Group (TGUG) Meetings with Associated Winter Workshop: The 27th and 28th USA Turbine Generator User Group meetings will be held in January, 2013 and August 2013, respectively. The location for the January meeting will be Savannah, Georgia (including a tour of the new Mitsubishi facility). The August meeting will be in Charlotte, North Carolina, with an associated tour of the Siemens turbine-generator facility.	12/31/13	Technical Resource

Product Title & Description	Planned Completion Date	Product Type
13th EPRI Steam Turbine-Generator Workshop and Vendor Exposition: In 2013, Program 65 will conduct the 13th EPRI Steam Turbine-Generator Workshop and Vendor Exhibition in Charlotte, North Carolina during the week of August 12. This workshop will include presentations by turbine-generator vendors and OEM's, utility personnel, and EPRI staff on technical issues such as inspection, condition monitoring, risk assessment, repair, retrofit, and life-extension relative to steam turbines, generators, and associated equipment. A vendor exhibition involving approximately 40 companies will be held on two evenings during the week.	12/31/13	Technical Resource
Generator Owner/Operator Technical Focus Group (Formerly NERC Compliance Interest Group): EPRI's GO/GOP Technical Focus Group represents the owners and operators of fossil, nuclear, and hydroelectric turbine generators for the purpose of collection and exchange of information on compliance with NERC standards. The group interfaces and collaborates on technical matters with other organizations, including the North American Generator Forum, North American Transmission Forum, and the generation subcommittees of the NERC regions. The group meets once a year and conducts regular conference calls.	12/31/13	Technical Resource
Comprehensive On-Line Generator Monitoring Interest Group: The goals of this interest group are to learn from industry experiences how to integrate the standard instrumentation (e.g., temperature, pressure, vibration sensors) with single-purpose on-line monitors (e.g., flux probe, partial discharge, shaft voltage, end-winding monitors) and to learn about different techniques that already have been implemented by others. Examples include generator field resistance and temperature monitoring to detect collector brush problems; shaft voltage monitoring to confirm presence of shorted rotor winding turns; and on-line detection of wet water-cooled stator winding. The group meets once a year during the meeting of the Fleet-wide Monitoring Interest Group (FWMIG).	12/31/13	Technical Resource
European TGUG Meeting: The 3rd European Turbine Generator User Group (TGUG) meeting and workshop will be held in April, 2013 at a location to be selected jointly by EPRI and member companies. It will include a two-day workshop with concurrent turbine and generator workshop sessions, followed by a one-day TGUG meeting.	09/30/13	Technical Resource
Steam Turbine-Generator Failures Yearly Report - 2013: This annual report contains member-submitted case studies of plant events related to turbine or generator component failures or operations-related issues. These case studies provide insights to guide proactive risk management strategies.	06/30/13	Technical Update
Technical Webcasts: Program 65 will conduct a series of seven technical webcasts on member-prioritized topics relating to steam turbine-generator condition monitoring, preventive maintenance, risk, and procurement practices. Webcast schedules are selected to fit international work schedules, and are recorded and posted on the Program webpage for future internal use by member company staff.	12/31/13	Technical Resource
Innovative Concepts for Turbine-Generator Engineers Information Delivery: This project will define, explore, and evaluate new and innovative techniques for disseminating research results to turbine and generator engineers. Working closely with member advisors, the project will use the results from this study to guide future research projects and ensure that research is delivered in a format that is effective and incorporates current technologies.	12/31/13	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Steam Turbine-Generator Failures Yearly Report - 2014: This annual report contains member-submitted case studies of plant events related to turbine or generator component failures or operations-related issues. These case studies provide valuable insights to guide proactive risk management strategies.	06/30/14	Technical Update
Australian TGUG Meeting: The 4th Australian Turbine Generator User Group (TGUG) meeting and workshop will be held in April, 2014 at a location to be selected jointly by EPRI and member companies. It will include a two-day workshop with concurrent turbine and generator workshop sessions, followed by a one-day TGUG meeting.	09/30/14	Technical Resource
Generator Owner/Operator Technical Focus Group (Formerly NERC Compliance Interest Group): EPRI's GO/GOP Technical Focus Group represents the owners and operators of fossil, nuclear, and hydroelectric turbine generators for the purpose of collection and exchange of information on compliance with NERC standards. The group interfaces and collaborates on technical matters with other organizations, including the North American Generator Forum, North American Transmission Forum, and the generation subcommittees of the NERC regions. The group meets once a year and conducts regular conference calls.	12/31/14	Technical Resource
Comprehensive On-Line Generator Monitoring Interest Group: The goals of this interest group are to learn from industry experiences how to integrate the standard instrumentation (e.g., temperature, pressure, vibration sensors) with single-purpose on-line monitors (e.g., flux probe, partial discharge, shaft voltage, end-winding monitors) and to learn about different techniques that already have been implemented by others. Examples include generator field resistance and temperature monitoring to detect collector brush problems; shaft voltage monitoring to confirm presence of shorted rotor winding turns; and on-line detection of wet water-cooled stator winding. The group meets once a year during the meeting of the Fleet-wide Monitoring Interest Group (FWMIG).	12/31/14	Technical Resource
Two Turbine Generator User Group (TGUG) Meetings with Associated Winter Workshop: The 29th and 30th USA Turbine Generator User Group meetings will be held in January 2014 and August 2014, respectively. The locations for the meetings will be announced in late 2012 and early 2013.	12/31/14	Technical Resource
Technical Webcasts: Program 65 will conduct a series of seven technical webcasts on member-prioritized topics relating to steam turbine-generator condition monitoring, preventive maintenance, risk, and procurement practices. Webcast schedules are selected to fit international work schedules and are recorded and posted on the program web pages for future internal use by member company staff.	12/31/14	Technical Resource
2014 EPRI Steam Turbine-Generator Technology Transfer Workshop and Vendor Exhibition: The 2014 Tech Transfer workshop will focus on transferring EPRI results to a wide variety of members, taking advantage of the opportunity to ensure that the research is being properly applied to maximize value to utility personnel. This workshop will focus on emerging issues as well as the most pertinent research results delivered in 2012 and 2013.	12/31/14	Technical Resource
Steam Turbine Performance Engineers Workshop: This biennial workshop focuses on identifying and correcting thermal performance impacts of turbine steampath deterioration. Performance testing methods and best practices are covered. Advances in new steam path component retrofit designs, such as blades and seal systems, also are covered.	12/31/14	Technical Resource

Supplemental Projects

NDE For Last-Stage Rotor Turbine Blade Attachments (070922)

Background, Objectives, and New Learnings

Pinned finger joints are a common design of several turbine manufacturers for the last-stage blade attachments. In this design, blade roots are stacked in inverse contour of the rotor and then locked by pins. During operation, the areas around pin holes are under high stress and are subject to cracking.

Project Approach and Summary

This project will expand on prior evaluations of complementary metal oxide semiconductor (CMOS) technology as a direct digital radiographic detector for cracking. Earlier projects determined that a CMOS detector currently available is fully capable of detecting cracking in boiler waterwall tubes while in place, and through insulation and other building structures around the boiler.

This project will consist of assembling a system, including optimization of CMOS detector parameters for high-energy X-ray sources; acquisition of the detectors; acquisition of a portable linear accelerator device; and development of data display software to accurately display the geometry of the rotor blade attachments. Once the prototype system is assembled and laboratory verification completed, a field trial will be conducted to verify operational feasibility and user friendliness.

Benefits

Complete ultrasonic examination cannot be performed with the blades in place, due to multiple interfaces associated with the attachment design that prevent the transmission of ultrasound. Only the outer finger section could be examined with that technology. The cost of blade removal, NDE, and re-assembly can approach nearly $1M and can lead to damage in the rotor. Because cracking and subsequent failure could occur at any of the attachment fingers, a need exists to examine the full attachment. High-energy radiography presents an opportunity to perform such an examination. The ability to use real-time digital radiography as the turbine is slowly rotating during the examination presents a means of detecting any cracking in less than one hour per stage.

Turbine Generator Users Group (069786)

Background, Objectives, and New Learnings

EPRI's Turbine Generator Users Group (TGUG) was chartered in the United States in January 2000 to address an industry need for improved information exchange on fossil and nuclear steam turbine-generator issues, maintenance practices, and risk management. Since TGUG's inception, membership has grown to include more than 70 power producers and seven steam turbine-generator manufacturers worldwide. The semiannual U.S. TGUG meetings are scheduled in conjunction with related Electric Power Research Center (EPRI) workshops and technical meetings to minimize travel costs for members. Meeting agendas are developed collaboratively by EPRI staff and the TGUG officers, who are elected from member organizations. The TGUG organization has now expanded to have groups in Australia, New Zealand, and Europe.

Project Approach and Summary

The objectives of the Steam Turbine/Generator Users Group are to:

- Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
- Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.

- Engage in activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This can include establishing working groups to address specific issues.
- Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components, and serve as a technical information resource for the industry on this topic.
- Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, original equipment manufacture (OEM) resolution, and utilize non-OEM contractor.
- Provide a forum in which OEM's, the Institute of Nuclear Power Operations (INPO), vendors, and utility personnel can interface and exchange ideas on topics concerning all types of steam turbines, generators, and associated systems and sub-components

Benefits

- Acquire and exchange information on maintenance, inspection, performance upgrades/uprates, repair, testing, storage, and handling of all types of steam turbine, generators, and associated systems and sub-components.
- Discuss and exchange information on applicable codes and standards related to all types of steam turbines, generators, and associated systems and sub-components.
- Engage in such activities that will improve the reliability and availability of all types of steam turbines, generators, and associated systems and sub-components. This will include establishing working groups, as needed, to address specific issues.
- Provide a forum for discussion of operation and maintenance of all types of steam turbines, generators, and associated systems and sub-components and serve as a technical information resource for the industry on this topic.
- Identify steam turbine, generator, and associated systems industry issues, and establish appropriate process for resolution — i.e., resolve within user group, initiation of a Program 65 (Steam Turbine-Generator and Auxiliary Equipment) project, equipment OEM resolution, and utilize non-OEM contractor.
- Provide a platform for OEM's, INPO, vendors, and utility personnel to interface and exchange ideas on topics concerning all types of steam turbines, generators, and associated systems and sub-components.

On-Line Monitoring of Generators and Large Motors Using Electromagnetic Signature Analysis (EMSA) Interest Group (063655)

Background, Objectives, and New Learnings

EPRI is seeking worldwide power generators interested in noninvasive, on-line monitoring of generators and mediumvoltage motors using electromagnetic signature analysis (EMSA, also known as EMI).

Project Approach and Summary

EMSA is used as a system-wide surveillance technique that can detect and identify, with a single test, electric insulation defects in a motor, generator, and associated electrical systems. The objectives of the interest group are to apply EMSA to power plant equipment (motors, generators, breakers, iso-phase bus) and to integrate it into existing predictive maintenance programs.

The group, which started in 2006, meets annually at participants' sites.

Benefits

Several conditions were identified on-line with EMSA and trended. In most cases, the trending allowed the repairs to be scheduled during outages. EMSA also verified the repairs were made properly. Documented benefit-to cost ratio exceeds 10:1.

Condition Assessment of Generator Stator End-Winding Using On-line Monitoring (072403)

Background, Objectives, and New Learnings

Several modern generators are experiencing severe end-winding vibration attributed to mechanical resonance. End-winding vibration, if not properly managed, can lead to phase-to-phase fault, phase-to-ground fault, or loss of phase. Some machines have been retrofitted with fiber-optic vibration sensors to monitor the machine behavior; however, there is little agreement of acceptable level of end-winding vibration. Consequently condition assessment using only vibration data is difficult and needs to be supplemented by visual inspection. EPRI report 1020234 "*Early Detection of Developing Generator Problems: Integrating Continuous on-Line Monitors*" suggests that end-winding vibration symptoms can be detected on-line with partial discharge (PD) and electromagnetic signature analysis (EMSA, also known as EMI). If the vibration is so severe that it causes the individual strands to crack, and if the circuit is repeatedly opened and closed, then intermittent sparking will be picked up by the PD/EMSA. However, it is not clear how much advanced warning PD and EMSA can provide before the end-winding vibration causes the strand(s) to break. Other endwinding vibration failure mechanisms, such as insulation abrasion of the phase or connection rings, also may be detectable. There is an industry need to investigate if the on-line vibration monitoring combined with electrical discharge can provide advanced warning of a failure.

Project Approach and Summary

EPRI is seeking generator owners/operators with air-cooled and hydrogen-cooled generators that are experiencing end-winding vibration. The units should be equipped with an end-winding vibration monitoring system and partial discharge bus couplers. The presence of end-winding resonance should be confirmed by off-line bump test or on-line vibration monitoring.

The approach is to perform long-term technical evaluation of two air-cooled and two hydrogen-cooled machines using a combination of on-line end-winding vibration monitoring, partial discharge, and electromagnetic signature analysis for condition assessment of generators with end-winding problems.

Benefits

It is expected that an increasing level of end-winding vibration will be detected in sufficient time to avoid in-service failure.