Steam Turbines-Generators and Auxiliary Systems - Program 65

Program Overview

Program Description

Up to 70% of outages planned for steam power plants involve work on the turbines. Power producers continually seek ways to optimize operation and maintenance activities on aging turbine-generator fleets. These activities can reduce maintenance costs, improve component reliability, and increase generator output. However, maintaining a detailed awareness of effective maintenance techniques is challenged by evolving operating experience, advanced materials and upgrade options, reduced staffing levels, and the retirement of experienced personnel.

The Electric Power Research Institute’s (EPRI’s) Steam Turbines-Generators and Auxiliary Systems program (Program 65) develops technologies and guidelines that help fossil and nuclear 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 plant operators to reduce operation and maintenance costs, maximize plant performance, and more effectively implement plant upgrades and asset management strategies.

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 can obtain information they can use to:
  - reduce maintenance costs
  - maintain high availability
  - 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 to:
  - 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

The program portfolio includes generating guidelines; analyses of the effects of flexible operation and unit upgrades and uprates; preventive maintenance (PM) guides; guidance on maintenance and repair optimization; risk assessment and advanced modeling technologies; performance assessment tools; and information exchanges, including reports, workshops, and users groups.

- Participants receive information on
  - T-G outage management
  - Unit maintenance intervals
  - T-G outage scope
- T-G alternative repair/replacement options
- Industry best practices for maintenance of turbines and generators
- Approaches and solutions to controlling corrosion in the low-pressure turbine phase transition zone (PTZ)
- Participants also receive information and technologies on turbine and generator
  - nondestructive examination
  - remaining life assessment
  - condition monitoring that supports risk management
- Participants are eligible to attend the Turbine Generator User Group meetings/workshops, the EPRI Steam Turbine Generator Workshop and Vendor Exhibition, and other workshops offered by the program.

Potential projects for each subsequent year's R&D efforts are discussed with the program member advisors during the current year's fall Generation advisory council meetings, where the members assist the P65 staff with prioritizing these R&D efforts. The number of projects completed each year is based on yearly funding levels coupled with this project prioritization list. These potential projects typically are identified during the year by program members, Turbine Generator User Group discussions, and at industry events.

Many members begin their participation in Program 65's R&D by joining the Turbine Generator Users Group (TGUG), a forum for sharing technical expertise among utilities and the six major T-G OEMs worldwide. TGUG is offered as a supplemental project in Program 65.

Accomplishments

EPRI's Turbine-Generator program is recognized in the industry as the authoritative source for up-to-date information on T-G issues and solutions in today's competitive environment. When members have uprated/upgraded existing units, performed unit scheduled or forced outages, evaluated component conditions and associated operational risks, or educated current T-G staff, these products have provided invaluable information and assistance:

- Staff education and training through turbine and generator workshops and seminars
- Turbine auxiliary systems maintenance guides for turbines and generators
- T-G outage reduction guidance
- T-G torsional vibration detection and mitigation
- T-G equipment and component repair and purchase specifications
- NERC regulation education and TG capability validation assistance
- T-G nondestructive evaluation (NDE) testing and application guidance
- Regular interaction with all major turbine and generator OEMs worldwide

A downloadable, comprehensive list of more than 200 current project deliverables from this TG program is available at www.epri.com under product ID 1016900.

Current Year Activities

The program R&D for 2011 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:

- Continued additions to the Guidelines for Reducing Time/Cost of TG Maintenance and Overhauls CD set
- Nanostructured Coatings for Improved Oxidation and Erosion of Resistance of Valve Materials Guide
- Completing Handbook for Steam Turbine and Generator Failure Identification
- Completing the Turbine Generator Auxiliary System Maintenance Guide: Vol. 7 Guide
- Completing PM Database Module Additions
- Completing Alternative Ultrasonic NDE Techniques for Detecting Fatigue-Related Material Life Consumption Guide
- Conducting two Turbine Generator User Group (TGUG) meetings with the associated winter workshop
- Conducting the Twelfth EPRI Steam Turbine-Generator Workshop and Vendor Exposition
- Conducting NERC Interest Group meeting as needed
- Completing a Short-term Shutdown of Steam Turbine-generators and Auxiliary Systems Guide
- Completing a Shipping Preparation and Long/short-Term Storage of Turbine and Generator Components Guide

Estimated 2011 Program Funding
$5.0M

Program Manager
Alan Grunsky, 704-595-2556, agrunsky@epri.com

### Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P65.001</td>
<td>Operations and Maintenance Cost Reduction</td>
<td>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.</td>
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<td>P65.002</td>
<td>Risk Assessment</td>
<td>This project provides emerging technologies for turbine-generator condition and component failure risk assessments. Risk assessment technology produces failure probability data that can be combined with maintenance and replacement power costs to assess financial risk.</td>
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<td>P65.003</td>
<td>Information Exchange for Plant Staff</td>
<td>Participation in this project's workshops and meetings allows utility personnel to quickly determine the most appropriate repair techniques, identify current industry experience and best practices in improving the reliability and availability of the unit, and transfer the technology developed by the overall T-G program into their maintenance practices systemwide.</td>
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P65.001 Operations and Maintenance Cost Reduction (052070)

Key Research Question
Power producers continually seek ways to optimize operation and maintenance activities as well as thermal performance in aging turbine-generator fleets. Reduced staffing levels and the retirement of experienced personnel have added challenges to meeting industry goals for equipment availability in the current competitive environment.

Approach
This project addresses core issues facing engineering staff today — reducing O&M costs and increasing thermal performance — by:

- Developing guidelines for T-G outage planning, disposition of damaged components, repair techniques, corrective actions, and specific maintenance practices
- Analyzing the effects of flexible operation and unit upgrades and uprates
- Producing preventive maintenance (PM) guides to include development of modules for the EPRI PM Basis Database
- Optimizing generator rotor maintenance, exciter maintenance, and retrofit and replacement guidance

Impact
- Decrease outage duration
- Increase outage intervals
- Improve repair of components
- Improve thermal efficiency
- Improve turbine-generator PM/Predictive Maintenance (PdM) process and practices

How to Apply Results
The documents produced and PM modules added to the PM database can be used when a utility is faced with equipment repair or testing or component condition assessment. Members can integrate the content in these guidelines in their own procedures and training materials. The guidelines can be placed on member utilities’ internal networks and provide an excellent resource for continuous improvement training, as well as new-hire orientation for system owners and maintenance staff. Utilities facing new equipment purchases can take advantage of the guidelines’ content in preparing their own site-specific procurement specifications.

2011 Products

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Guidelines for Reducing Time/Cost of T-G Maintenance and Overhauls (2011): This project will add material to the seven-volume set of guidelines first generated in 1999 and updated every year since. New material will continue to focus on turbine-generator centerline components, with an emphasis on maintenance, repair, and procurement processes before, during, and after an outage. The objective is to educate plant staff on how to reduce time and cost of turbine-generator outages through better pre-planning and repair/replacement strategies and techniques during the outage.
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<tr>
<td><strong>Nanostructured Coatings for Improved Oxidation and Erosion of Resistance of Valve Materials:</strong> Erosion of valve surfaces from exfoliated oxides, and oxidation of valve internals such as stems, reduce steam valve operational reliability and life. Various materials and surface modifications such as nitriding have been used with varying degrees of improvement, but high erosion rates remain. Nanostructured coatings, developed by EPRI's Technology Innovation (TI) program for gas and steam turbine blades, can provide surface hardening with improved oxidation resistance compared to bare metals and standard coatings. In 2010, this project, performed jointly with Program 87 (Fossil Materials and Repair), identified potential nanostructured coatings, applied them to a valve stem, and evaluated the coating integrity. In 2011, it will install a coated stem in the field and monitor its performance.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<td><strong>PM Database Module Additions:</strong> The Preventive Maintenance Basis Database (PMBD) serves the utility maintenance community as an essential reference for maintenance strategy task selection on common major components. The PM Basis Database software, Version 2.1 (Product ID: 1018750), is the most comprehensive effort undertaken to date to establish credible preventive maintenance (PM) recommendations and their supporting basis for the utility industry. More than 150 modules already exist in the database with T-G modules to be added in 2011. PM modules will continue to be added to the PM Basis database from completed TG projects.</td>
<td>12/23/11</td>
<td>Software</td>
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<td><strong>Determination of Appropriate 0.1 Hz Hipot Levels for Modern Stator Winding Insulation:</strong> New generator and motor stator windings are Hipot tested in the factory with alternating current (ac). Maintenance testing at the plant usually is conducted with equivalent direct current (dc) voltage because of significantly smaller test equipment size/expense. Very-low-frequency (VLF) 0.1 Hz testing routinely is used on installed cables. VLF test sets are small, inexpensive, and readily available, and a water-cooled stator winding can be tested with water present. The objectives of the project are to document scientific data to define the ratio between 60 and 0.1 Hz test levels for epoxy–mica insulation. The project started in 2010; the deliverable date is 12/31/2011.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<tr>
<td><strong>Generator Stator End-Winding Vibration Guide:</strong> Several modern generators have experienced severe end-winding vibration attributed to resonance close to twice the grid frequency. The objective of this project is to create a comprehensive guide for generator stator end-winding vibration.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<td><strong>Turbine Generator Auxiliary System Maintenance Guide- Vol. 7:</strong> The existing six volumes of the Auxiliary System Maintenance (ASM) Guides include Lube Oil System, Steam Seal System, Generator Hydrogen Gas System, Generator Stator Cooling System, EHC/MHC Emergency Trip System, and Turning Gear System. Volume 7 will address the generator excitation system. This addition to the ASM Guides will expand the reference information available to EPRI members.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<td><strong>Evaluation of Flow Guide/LP Turbine Exhaust Hood Improvements:</strong> The modification of flow guides and/or LP turbine exhaust hoods can be an opportunity for heat rate and potentially reliability improvements. The cost of these modifications has decreased with the widened use of computational fluid dynamics (CFD) modeling. These modifications can be completed during LP turbine overhauls and may become part of an LP turbine replacement or upgrade and augment the gains realized. This project will quantify the expected gains in heat rate and reliability and weigh those against the costs for engineering, fabrication, and installation.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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**Product Title & Description**

| **Cost-Benefit Evaluation of Admission Schemes to HP Turbines:** After operating in partial arc admission for years, following recent turbine modifications or upgrades, many power plant operators are now operating in full arc. This change brings potential efficiency changes, depending upon the load scheme of the units. With the recent changes in demand, creating situations of increased load following and unit cycling, the economics behind that change to full arc admission may be quite different. This project will evaluate the operating differences between full and partial arc admission, quantify the expected changes in heat rate and reliability, and weigh those against the cost differences between full and partial arc admission. |
| Planned Completion Date |
| 12/23/11 |
| Product Type |
| Technical Report |

| **Handbook for Steam Turbine and Generator Failure Identification:** Several programs in the EPRI Generation sector have produced handbooks suitable in size to be conveniently carried into the plant to assist plant personnel in identifying component failures modes. These handbooks also contain photos of various failures, inspection techniques, and remedial/prevention actions that the utility can adopt to prevent such failures. In 2011, Program 65 will produce a similar handbook on steam turbine and generator failures. |
| Planned Completion Date |
| 12/23/11 |
| Product Type |
| Technical Resource |

**P65.002 Risk Assessment (052072)**

**Key Research Question**

Risk assessment is an increasingly important aspect of both short- and long-term planning. Managing risk requires a combination of advanced inspection techniques, new nondestructive evaluation (NDE) technologies that reduce inspection time and increase accuracy, analytical tools to address component cracking, and corrosion degradation modeling.

**Approach**

This project provides emerging technologies for:

- Guidance in run/repair/replace decisions, plant life extension, life-cycle management, and overall optimal use of capital resources
- Turbine-generator condition assessment and component failure risk assessment
- Risk-assessment technology, producing failure probability data that can be combined with maintenance and replacement power costs to assess financial risk
- Emphasis on NDE of turbine-generator components, condition assessment, and remaining-life assessment
- Completion of advanced modeling of corrosion-assisted cracking, including delivery of a corrosion cracking prevention guide

**Impact**

- Accurately assess risk with plant turbine-generator upgrades and maintenance
- Investigate emerging technologies for assessing turbine-generator condition and component failure risk

**How to Apply Results**

The EPRI technology produced by this program will enhance the ability to analyze and quantify the risks associated with component failure, replacement, upgrades, and uprates. Members can use the information from this project to customize their turbine operations windows, in order to assess the economic impact of applying the methodologies such as those contained in the Turbine Blade Vibration Monitoring report. Access to improved inspection mockups allows members to more confidently evaluate nondestructive inspection systems and personnel.
## 2011 Products

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<td><strong>Generator On-Line Monitoring Using Enhanced EMI (Electromagnetic Interference) Diagnostics:</strong> Condition assessment based on information from continuous on-line monitoring can prevent forced outages and reduce the amount of emergent work during scheduled outages. Foreign objects, loose current-carrying parts, and compromised electrical insulations or connections in or around motors and electrical generators cause sparking that can be detected online and in a noninvasive manner by devices designed to measure/detect electromagnetic interference. The interpretation of EMI signature to detect the source of sparking requires a great amount of experience. The goal of this effort is to make the interpretation less dependent on experience. Rensselaer Polytechnic Institute has independently developed an electromagnetic propagation model that can be used to separate the signal caused by a sparking defect from the overall EMI signature of the generator. The objective of this project is to develop a user-friendly software to model any large generator without the need for OEM design data.</td>
<td>12/23/11</td>
<td>Software</td>
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<td><strong>Risk Assessment of Generator Rotor Damage Following Operation Under Electrically Unbalanced Condition: Validation:</strong> 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, stuck circuit breaker pole, and accidentally connecting the generator to the grid when at standstill can cause the generator rotor surface to overheat. In 2010, EPRI developed an MS Excel® program to quickly assess the risk of allowing the unit to operate safely after such incident. The objectives of the project are to validate the software and to implement any changes based on field experience.</td>
<td>12/23/11</td>
<td>Software</td>
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<tr>
<td><strong>Non-Intrusive Methods to Validate NERC Standards: Lessons Learned:</strong> In 2009, EPRI released software that automatically matches the model response of the turbine controls and generator electrical output to the recorded disturbance. The Power Plant Parameter Derivation (PPPD) software includes a suite of Institute of Electrical and Electronics Engineers (IEEE) models for generators, generator excitation systems, combustion, and steam turbines. The project objective is to document utility experience with the PPPD software.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<tr>
<td><strong>Alternative Ultrasonic NDE Techniques for Detecting Fatigue-Related Material Life Consumption:</strong> Steam turbine blade failures are a common reason for unplanned outages. The damage associated with failure of large, low-pressure blades can be extensive and costly. Many nondestructive inspection methods and technologies exist to detect cracking that already has occurred. However, standard nondestructive inspection technologies are not able to predict cracking before it occurs. Fatigue sensor technology has been qualitatively proven as a technology for identification of fatigue damage accumulation and life consumption. This project, which began in 2009, will continue conducting quantitative benchmarking of this technology using 12 CR fatigue test specimens to provide a detailed quantification of the fatigue damage measurements and its uncertainty using existing technology. Results of this project will be applied to development of field inspection procedures using fatigue sensor technology.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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<tr>
<td><strong>Update to Bearing Failure Manual:</strong> Turbine bearing failures continue to cost the utility industry unplanned outage time and cause significant damage when major failures occur on operating equipment. In 1991, EPRI produced a manual of bearing failures (product CS7352), which classified bearing failures and offered tools for a correct diagnosis of the mode of failure. This project will update this manual on current technology relative to detecting failures prior to catastrophic failure, diagnosing the failure mode and repair options.</td>
<td>12/23/11</td>
<td>Technical Report</td>
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Product Title & Description                                      Planned Completion Date | Product Type
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Turbine Generator Materials Cross Reference Guide: Much information has been produced by EPRI over the years relative to the material characteristics and properties of turbine and generator components. This product will gather this type information into one reference manual to help utility technical staff to better characterize and identify these component material properties from existing EPRI technical documents. | 12/23/11 | Technical Report

P65.003 Information Exchange for Plant Staff (052076)

Key Research Question

Use of EPRI material and products in members’ plants is made more difficult by decreasing staff and loss of expertise. For example, an estimated 30% of the U.S. nuclear workforce will be eligible to retire in the next five years. New employees need a much faster, more efficient method to gain knowledge of plant equipment and the problems and issues associated with operating and maintaining their equipment.

Approach

One of the most effective ways for plants to reduce operating cost is to apply the lessons that others have learned in addressing common reliability and maintenance issues. This program will help members share up-to-date information, including industry experiences, data, and turbine-generator (T-G) problems for common equipment. Participation in the Turbine Generator User Group, the T-G Technology Transfer workshops, technical webcasts, and the Steam Turbine Generator Workshop and Vendor Expositions educate plant engineering staff about resources available through EPRI and the industry that can help solve their operating and maintenance problems.

Impact

- Increase turbine-generator staff expertise
- Apply other utilities’ lessons learned
- Be aware of emerging issues
- Establish and maintain direct contact with industry peers and T-G OEMs and vendors

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 this program. 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 OEM guidance.

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

- EPRI T-G Technology Transfer Workshop and Steam Turbine Generator Workshop and Vendor Exposition
- Winter/Summer 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 appropriate to their time zone schedules
2011 Products

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<td><strong>NERC Compliance Interest Group:</strong> This interest group was formed to share compliance experience with respect to standards approved and proposed by the North American Electric Reliability Corporation that apply to power plants. The project will consist of webcasts, conference calls, and an annual meeting. The group will continue to meet in 2011. Exact meeting date TBD.</td>
<td>12/23/11</td>
<td>Technical Resource</td>
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<td><strong>Comprehensive On-Line Generator Monitoring Interest Group:</strong> Comprehensive on-line generator monitoring seeks to integrate 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). The logic rules needed for data interpretation will reside in the plant computer. The project will consist of webcasts, conference calls, and an annual meeting to help the participating engineering, maintenance, and IT personnel to implement comprehensive on-line generator monitoring. The group will continue to meet in conjunction with the Fleet-wide Monitoring Interest Group.</td>
<td>12/23/11</td>
<td>Technical Resource</td>
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<td><strong>Conduct Two Turbine Generator User Group (TGUG) Meetings with the Associated Winter Workshop:</strong> This project's traditional two meetings per year in the United States will continue in 2011. The January 2011 workshop and meeting will be held in Houston, Texas (to include a tour of the nearby TurboCare blade manufacturing facility) the week of January 17, and the summer meeting (held in conjunction with the Twelfth EPRI Steam Turbine Generator Workshop and Vendor Exhibition) will be held August 10-12 in Chattanooga, Tennessee.</td>
<td>12/23/11</td>
<td>Technical Resource</td>
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<td><strong>12th EPRI Steam Turbine-Generator Workshop and Vendor Exhibition:</strong> In 2011, Program 65 will conduct the 12th EPRI Steam Turbine-Generator Workshop and Vendor Exhibition in Chattanooga, Tennessee during the week of August 8. This workshop will include presentations by turbine-generator vendors and OEM's, utility personnel, and EPRI staff on issues and solutions to problems in the electric utility industry relative to steam turbines, generators, and associated equipment. A vendor exhibition will be held on two evenings during the week. Past vendor exhibitions have featured 35-50 vendors/OEMs.</td>
<td>12/23/11</td>
<td>Technical Resource</td>
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<tr>
<td><strong>Steam Turbine-Generator Failures Yearly Report:</strong> For the past two years, Program 65 has issued a yearly report on major turbine and/or generator failures, based on information gathered from our members. Past reports have included information such as a summary of the individual failures, root cause analysis, pictures, and outages reports. This report will be produced again in 2011.</td>
<td>12/23/11</td>
<td>Technical Update</td>
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