Combustion Turbine (CT) and Combined-Cycle (CC) O&M - Program 79

Program Overview

Program Description

Cycling and high-temperature operations adversely affect combustion turbine component life as well as plant reliability and availability. Controlling the high costs associated with hot-section life cycle is critical. The risks associated with compressor failures, rotor cracks, and combustor dynamics must be cost-effectively managed. Improved operational flexibility, such as NO_x (dry low-NO_x (DLN)) combustor turndown and plant startup, would help plants address load demands.

The Electric Power Research Institute's (EPRI's) Combustion Turbine (CT) and Combined-Cycle (CC) O&M program (Program 79) provides comprehensive resources to address the operation and maintenance (O&M) needs of conventional simple-cycle combustion turbines and advanced heavy-frame machines in simple- and combined-cycle operation.

Research Value

Members of this program can use the R&D to manage equipment risks through root cause and engineered solutions; reduce life-cycle costs through repair technology and improved component design; and enhance overall plant operational flexibility by reducing combustor issues, mitigating cycling damage, and increasing performance. Specifically, members can:

- Reduce life-cycle combustion turbine/combined-cycle (CT/CC) plant O&M costs by at least 25% without increased risks
- Improve O&M costs through in-depth understanding of O&M issues at the model/sub-model-specific level
- Gain objective, expert assessments of original equipment manufacturer (OEM) and independent offerings in addition to O&M recommendations
- Benefit from O&M experience and resources through collaborative interactions

Approach

Program activities address monitoring and inspection, repair technique improvement, component life prediction, and plant O&M management tools. The model-specific design features are directly addressed in product development. Members use the R&D for:

- Risk management—early detection, root cause and solutions R&D uses in-depth studies of high-risk component issues to identify root cause failure mechanisms and to develop and demonstrate corrective/damage mitigation solutions.
- Research into O&M improvements—life prediction, component design, and repair research provides model-specific repair, procurement, and damage tracking guidelines for hot-section, combustor, and compressor components.
- Operational flexibility—capacity, performance, combustion dynamics, and emissions R&D produces techniques for improving interrelated machine operational characteristics, such as tuning and turndown of DLN systems and mitigating cycling damage.
- Plant productivity support tools and training, which provide O&M cost analysis software and overhaul planning tools for different models, as well as training courses for applying EPRI products.

Accomplishments

EPRI's Combustion Turbine and Combined Cycle O&M program has provided high-quality technical evaluations and products to support better operations and maintenance for more than 30 years, including:

- Model-specific repair guidelines for widely used 50/60-Hertz (Hz) machines
- Replacement part procurement guidelines for D/E- and F-Class models
- Compressor and rotor root-cause analysis and O&M solutions
- Improved maintenance interval criteria for hot section components

Current Year Activities

Program R&D for 2010 will seek to mitigate advanced machine dependability issues and reduce conventional machine O&M costs. Specific efforts will focus on:

- Root causes of recurring failures and durability shortfalls
- Cost-effective approaches for addressing compressor, combustor, and rotor dependability
- New and updated repair guidelines for 50/60-Hz models
- New and updated procurement guidelines for D-, E-, and F-class models

Estimated 2010 Program Funding

$2.5M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P79.001	Risk Management: Early Detection, Root Cause and Solutions	In-depth investigations and guidelines address high-risk component failure root cause mechanisms. Corrective solutions and damage mitigation techniques are developed, evaluated, and demonstrated.
P79.002	O&M Improvements: Life Prediction, Component Design and Repair	The project provides model-specific repair, procurement, and damage tracking guidelines for hot section, combustor, and compressor components.
P79.003	Operational Flexibility: Capacity, Performance, Combustion Dynamics and Emissions	This project provides techniques for improving interrelated machine and plant operational characteristics, such as emissions and turndown of DLN systems, part-load performance, or full-load megawatt capacity production.
P79.004	Plant Productivity Support Tools & Training	This project provides O&M cost analysis software and overhaul planning tools for different models, as well as combined-cycle plant equipment O&M guidelines and special studies, and develops training courses to assist with the application of EPRI products.

P79.001 Risk Management: Early Detection, Root Cause and Solutions (067357)

Key Research Question

The effective operation of complex, tightly integrated combustion turbines (CT) requires astute monitoring, regular inspection, understanding of the critical damage mechanisms and root causes, and engineered solutions to maintain high availability and reliability. This requirement is particularly true for advanced machines, where cascading failures can cause more than $10 million in equipment damage. These types of major equipment risks are not usually addressed by service agreements and only partially covered by insurance.

Approach

This project helps members with early detection of incipient damage, as well as in-depth understanding of damage mechanisms and the underlying root causes driving accelerated deterioration and increased risk of outright failure.

- Cost-effective risk management needs to be tailored to the specific machine model and issue in the compressor, combustion system, or hot section. The project develops and validates inspection and monitoring techniques, collects field experience, characterizes component design features, develops detailed engineering models, and evaluates damage mitigation and corrective design measures.
- In the compressor, work is aimed at understanding and mitigating the impacts of extensive rubbing, erosion/corrosion, deposit buildup, foreign object damage (FOD), and stall/flutter flow excitations contributing to blade and stator failures.
- In the combustion system, techniques to detect dry low-NO_x burner instabilities leading to fuel nozzle failure and downstream hardware damage are being developed.
- In the turbine hot section and rotor, material testing and design analysis are used to assess risks from high-temperature creep/oxidation, thermo-mechanical fatigue cracking, and reduced fracture toughness/embrittlement of costly superalloy and CrMoV components. Detailed component failure and stress analysis is often covered in supplemental projects.

Impact

- Mitigate damage by using improved monitoring and inspection techniques to provide advance notice to CT owners of abnormal conditions and the opportunity to take countermeasures.
- Cost-effectively reduce the risk of high impact-failures by understanding damage mechanisms and their root causes, and adjusting maintenance accordingly.
- Develop, evaluate, and demonstrate engineered solutions, including design modifications that effectively address the root causes.

How to Apply Results

Investigation reports of root cause failure and damage provide technical background to define flaw size for inspection, adjust operating practices, and evaluate possible design modification. An engineered solution may require the involvement of the OEM, repair shop, or other service provider. Monitoring techniques are customized to the model type and plant configuration. The plant or remotely located monitoring center installs the software with appropriate connections to the plant process data historian.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Component Failure Investigations and O&M Risk Mitigation Guidance: Compressor, combustor, and rotor component deterioration and failure are investigated for specific models. Metallographic analysis, material property testing, and stress modeling, coupled with machine operating characteristics, are used to understand the causes. Component models are used to develop and screen possible solutions. O&M guidelines provides practical information for plant level implementation.	12/31/10	Technical Update
Demonstration and Validation of Component Modification and Damage Mitigation Techniques: The effectiveness of new coatings, component modifications, remote inspection, or monitoring techniques are demonstrated and validated. Additional R&D may be identified to further improve or refine component designs or O&M procedures.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Component Failure Investigations and O&M Risk Mitigation Guidance	12/31/11	Technical Update
Demonstration and Validation of Component Modification and Damage Mitigation Techniques	12/31/11	Technical Update

P79.002 O&M Improvements: Life Prediction, Component Design and Repair (067358)

Key Research Question

Combustion turbines (CT) require extensive repair and refurbishment at predetermined intervals due to very high-temperature operation. Superalloy blades, vanes, and combustion hardware depend on effective repairs to achieve their stated economic life. Due to the high cost of repairs (for example, an F-class first-stage blade replacement can cost $2–4 million per row), the need for in-depth guidance is critical. Fallout rates (i.e., for parts deemed not repairable at the prescribed strip/recoat interval) have exceeded 50% for certain high-temperature combustion turbine models. For mature designs, extending run intervals may be possible with design and material testing qualification. Compressor O&M issues include rubbing, tip cracking, foreign object damage, erosion, corrosion, aerodynamic stall/flutter, and surge. Repair service providers and aftermarket parts suppliers may offer competitive alternatives to the original equipment supplier for innovative design/repair solutions.

Approach

Effective management of combustion and hot-section life-cycle costs focuses on three elements: optimizing the maintenance interval, extending service life by repair, and obtaining lower-cost/longer-life replacement hardware. EPRI offers R&D supporting all three elements:

- Damage tracking guidance is based on extensive durability analyses that provide objective estimations of creep, oxidation, and thermal mechanical fatigue damage to specific components locations as a function of operation. EPRI maintains and continues to expand a series of CT component repair guidelines covering combustion/hot-section hardware for 50/60-Hz conventional and advanced models. Currently available model-specific volumes cover: GE 7B, 6B, 7FA, 9FA, 7E/EA, 9E; Siemens-Westinghouse

W501A-D, W501D/D5A, W501F, V84.2, V94.2, V84.3A, V94.3A; Alstom 11N2, GT24; and Mitsubishi M501F, M701F.

- A series of procurement guidelines for replacement of superalloy components provide technical criteria for nondestructive examination, acceptable coatings, qualification/approval of master heats, dimensional conformity, manufacturing and heat treatment, metallurgical requirements, and quality assurance. Also included is repair technology development using novel welding, brazing, and geometry modifications.
- To facilitate the application of guidelines, EPRI routinely issues reports surveying the capabilities of repair shops and aftermarket parts suppliers.

Impact

- Reduce fallout from repair cycles and possibly extend overall economic life using the damage tracking guidance to optimize maintenance intervals.
- Achieve cost savings from competent, cost-effective refurbishment services made possible by the repair guidelines.
- Reduce replacement hardware costs by procuring more durable designs and competitive bidding.

How to Apply Results

Repair and procurement guidelines as well as related supplier capability surveys are used to support competitive bidding. The guidelines are designed to be incorporated into a technical specification bidding document. The repair criteria are used to safely guide refurbishment and identify key quality issues. Damage tracking guidance can be used to make manual estimations of component maintenance intervals or incorporated into the plant's automated monitoring system. Project information is also useful in managing long-term service agreements.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
CT Repair Guidelines: New and Updated Model-Specific Volumes: Each CT model is covered in a separate repair guideline volume. Information relating to compressor and hot section designs are covered in separate volumes. The 16-volume series is regularly updated and expanded to include new component features, general repair approaches, and quality assurance measures.	12/31/10	Technical Update
Procurement Guidelines for Improved Components: New and Updated Model-Specific Volumes: Individual guidelines for model-specific parts (such as blades, vanes, ring segments, and select combustion hardware) detail dimensional conformity, metallurgical quality, production casting mechanical property testing, nondestructive examination, test reports and records, marking and packaging, and quality assurance. Model types addressed by the guidelines include 6B, 7E/EA, 9E, 7FA, 9FA, V84.3A, V94.3A and V94.2.	12/31/10	Technical Update
Component Durability Analysis and Damage Tracking: Component durability models consist of 3-D aerothermal stress finite element modeling, which captures all the design detail including advanced cooling schemes and protective coatings. Steady-state and transient analyses, coupled with metallurgical examination of service-aged components, provide an in-depth understanding of the governing damage mechanism and weak-link locations. Insights from the models are used to improve repair procedures, optimize maintenance intervals, and assess design modifications.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Repair Shop and Alternative CT Component Supplier Capabilities - Update: EPRI routinely surveys repair shop and alternative parts supplier capabilities. Reports cover both North American and international repair service providers and alternative parts suppliers. Topics include experience level with specific model parts, unique component design features or repair approaches, and near-term plans for new offerings, especially related to E- and F-class models.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
CT Repair Guidelines: New and Updated Model-Specific Volumes	12/31/11	Technical Update
Procurement Guidelines for Improved Components: New and Updated Model-Specific Volumes	12/31/11	Technical Update
Component Durability Analysis and Damage Tracking	12/31/11	Technical Update
Repair Shop and Alternative CT Component Supplier Capabilities Update	12/31/11	Technical Update
Advanced Repair Development and Qualification	12/31/11	Technical Update

P79.003 Operational Flexibility: Capacity, Performance, Combustion Dynamics and Emissions (100579)

Key Research Question

Plants required to cycle generally suffer from accelerated degradation, reduced availability, and increased O&M costs. The challenge in cycling combustion turbine plants lies in the interrelationship of capacity, performance, and emissions combined with high transient stresses in hot-section components. The combustion system is often the limiting factor in turndown, while thick-walled components in downstream combined-cycle equipment can slow startups. The NO_x (DLN) combustor is particularly sensitive to changes in fuel quality and ambient conditions, which is a concern for LNG global fuel supply.

Approach

This project examines the impact of design limitations on various operational flexibility issues, leading to solution developments and field validation. The near-term focus is on combustor dynamics and emissions of particular concern for the DLN and conventional diffusion-flame designs using extensive water/steam injection. Techniques for monitoring damaging dynamic events and procedures for improved tuning are helping demystify premixed combustion systems. All aspects of combustion inspection (CI) maintenance, including nozzle flowing, optimal maintenance intervals, and extended service hardware modifications, will be addressed. Other supplemental work addresses fuel impacts, such as the consequences of firing syngas or liquid fuels derived from coal or various green biosources. The project has developed extensive background information about capacity enhancement techniques, such as foggers, chillers, and evaporative coolers.

Impact

- Improve O&M of conventional and dry low-NO_x combustors by using model-specific guidance.
- Understand the limitations of fuel interchangeability and possible issues with broader fuel supply sourcing.
- Boost megawatt production through extensive background information on capacity enhancement techniques.
- Improve overall operational flexibility by introducing field-validated plant modifications.

How to Apply Results

The guidelines and reports are used in conjunction with combustor inspections and improvements to system operation, such as overseeing the regularly scheduled refurbishment or adjusting fuel splits. Reports provide the necessary understanding to anticipate possible fuel impacts and methods to accommodate wider quality variations via monitoring, combustor adjustment, and equipment modifications. Reports help identify possible equipment and control modifications to enhance certain aspects of improving plant operational flexibility.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
DLN Combustor O&M Guidelines: New and Updated: Combustor tuning, monitoring, and overhaul guidelines are available for the GE DLN 1.0, 2.0, and 2.6 versions. Work continues to enhance guidelines and add new DLN systems for other gas turbine suppliers, especially in reflowing criteria for nozzles and other hardware. Modifications and adjustments to enhance combustor turndown while maintaining emissions and avoiding instabilities are included. This understanding of combustor behavior will be extended to adjustments needed to accommodate the impacts of wide Wobbe gases such as LNG.	12/31/10	Technical Update
Plant Operational Flexibility Modifications: Reports detail offerings and experiences in improving plant operational flexibility and documenting modifications to the CT and steam cycle. Plant modifications to improve startup ramp rates, improve fuel flexibility, reduce emissions, enhance megawatt production, or mitigate general equipment wear and tear are identified. Case histories and plant data establish the effectiveness of such modifications.	12/31/10	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Capacity Enhancements: New Techniques and Operational Impacts	12/31/11	Technical Update
Plant Performance Degradation and Efficiency Recovery/Improvements	12/31/11	Technical Update

P79.004 Plant Productivity Support Tools & Training (100574)

Key Research Question

Plant managers, engineers, and operators must continually re-examine the effectiveness of their O&M procedures and identify areas for improvement. These include maintenance timing, risk management, staff renewal, parts sparing, overhaul planning, and optimal budgeting. Information from outside the company is often required for effective benchmarking and to help define effective, achievable goals.

Approach

This project addresses some of the key combustion turbine/combined-cycle O&M concerns not covered in other parts of the program. Resources provided include:

- A guidebook covering general CT O&M costs and operating practices, which is updated periodically. Reliability, availability, and maintenance (RAM) plant data help establish meaningful benchmarks that can be related to equipment type and plant operating mission.
- The INTURB CT owner's directory, which facilitates contacting peers to share information about model-specific reliability.
- A series of O&M guidelines that address axial compressor performance, predictive maintenance implementation, and selective catalytic reduction (SCR) systems.
- A series of software packages, called the Gas Turbine Overhaul Plan (GTOP), provide model-specific detailed disassembly, inspection, and re-assembly task breakdowns. Current GTOP models include the GE Frame 7B, 6B, 5, 7FA, 9FA; Siemens-Westinghouse W501AA-D, V84.2; and Alstom GT11N/N1, N2, 11D, with others planned.
- The CTCC O&M Cost Analyzer, which enables overall cost assessment of maintenance strategies, including service agreements, operational cost impacts, and self-maintenance options.
- Training courses and workshops that help members apply the program products.

Impact

- Manage outages more effectively by using a detailed, model-specific overhaul plan with task-by-task breakdown structure.
- Benchmark and develop best practices by applying RAM data and sharing information with peers.
- Develop detailed modeling and costs for examining operational impacts and changes in maintenance strategies using the CTCC O&M Analyzer.
- Identify and troubleshoot a range of equipment problems by employing the plant equipment guidelines.

How to Apply Results

GTOP software is used directly in the outage planning process. The task database can be transferred to other popular maintenance management software. O&M guidelines are kept at the plant as a readily available reference. EPRI training improves staff general technical understanding and application of specific EPRI products. The CTCC O&M Analyzer typically requires two to three hours of web-based training, after which staff can evaluate specific machine life-cycle economics.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
CTCC O&M Cost Analyzer: Update Version: Excel spreadsheet-based software estimates the O&M costs for simple-cycle and combined-cycle plants for user-specified operating scenarios. CT model-specific maintenance costs are based on component replacement and repair costs, life estimates, and maintenance intervals. (Product shared with Program 80, Project 80.003.)	12/31/10	Software
Equipment O&M Guidelines: New and Updated: O&M guidelines and related special studies address CTCC plant equipment such as SCR and CO catalyst deactivation, electric generator issues, and other balance-of-plant equipment. Factoring in plant experience is a key element in this product.	12/31/10	Technical Update
Training Courses and Workshops for Improved O&M: Training course material is developed to support the application of program products. The Hot Section Life Management course covers superalloy repair and coating processes, combined with considerations for model-specific component features. A complementary course addresses hot section component procurement, reviewing the design and hardware manufacturing with a form-fit-function perspective. Another course addresses combustion system overhaul and tuning procedures. Webcast training sessions are also available for the Gas Turbine Overhaul Plan and CTCC O&M Cost Analyzer.	12/31/10	Workshop, Training, or Conference
Gas Turbine Overhaul Plan (GTOP): New and Updated: A database of approximately 300 tasks covers detailed steps in machine disassembly, inspection, and re-assembly suitable for managing a combustion inspection, hot gas path inspection, or major overhaul. Man-hours, tooling, and craft type are included in each task. The software platform is Microsoft Project, but the task database is transferable to other planning software. Maintenance procedures and inspection forms can be linked to create a complete overhaul record.	12/31/10	Software
CT Owners INTURB Directory: Annual Update: This database contains information on more than 5,600 sites and 3,400 contacts worldwide to promote communications between owners and operators of gas turbines. Information on company sites and contacts is updated throughout the year.	12/31/10	Technical Resource

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Gas Turbine Overhaul Plan (GTOP): New and Updated	12/31/11	Software
Equipment O&M Guidelines: New and Updated	12/31/11	Technical Update
CTCC O&M Cost Analyzer: Update Version	12/31/11	Software
CT Owners INTURB Directory: Annual Update	12/31/11	Technical Resource
Training Courses and Workshops for Improved O&M	12/31/11	Workshop, Training, or Conference