New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection - Program 80

Program Overview

Program Description

Electrical capacity and generation from natural gas fuel are forecasted to increase in the coming years. Combustion turbines often are selected due to their lower capital costs compared to coal and nuclear energy. Even when renewable energy is added, gas turbine capacity may be needed to complement intermittent wind and solar generation. Recently, gas supply reserves have been revised upward based on significant additions from shale formations and new liquefied natural gas (LNG) sources. Gas turbine and combined-cycle technologies continue to evolve, resulting in significant efficiency gains and relative improvements in installed cost. These factors, combined with a general trend towards less carbon-intensive generation, portends an expanding role for gas turbines and combined-cycle plants.

Informed decisions on gas turbine technology and plant designs are especially important because they can have a profound impact on operability and performance. Technology selection affects efficiency, emissions, availability, maintainability, and durability. Appropriate environmental control technologies are needed to meet regulatory requirements. The ability to fire fuels of variable composition is critical for future refueling options. Flexible operational capabilities are needed for optimal plant dispatch, and planners need to understand coming trends and potential improvements for future growth.

The Electric Power Research Institute's (EPRI's) New Combustion Turbine/Combined-Cycle (CTCC) Plant Design and Technology Selection program (Program 80) provides the information and analysis needed to select combustion turbine technologies and specify combined-cycle plant designs for today's new generation requirements while planning for future technological advances.

Research Value

The research in this program helps engineers and project developers give new plants the flexibility to start quickly, operate efficiently at varying loads, and fire fuels of varying composition while meeting regulatory emission limits. Improved gas turbine plant profitability is achieved through an overall life-cycle approach, which includes a balanced understanding of capital and O&M costs, performance improvements, and technical risks associated with new high-efficiency turbine designs and the market contexts in which they operate. The program focuses on addressing the most significant plant design improvements that differ from the previous combined-cycle buildout.

- Optimal technology selections and designs increase plant profitability, reduce overall life-cycle costs, and improve operability.
- Managing technology risk helps control operation and maintenance expenditures.
- Objective, expert assessment of technology trends and worldwide experience can improve procurement decisions.

Approach

Up-to-date information and evaluations enable better procurement decisions and help minimize costs while optimizing plant performance, reliability, and operational flexibility for simple-cycle and combined-cycle combustion turbine plants.

- Combustion Turbine Experience and Intelligence reports and project risk reports provide concise analyses of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability issues, maintenance strategies, industry trends, and related market conditions.

- CTCC technology durability, design, and performance reports cover original equipment manufacturer (OEM) combustion turbine product lines, including design features, related risk concerns, and Reliability, Availability, Maintainability-Durability (RAM-D) experience. All 50-Hz and 60-Hz models over 20 megawatts (MW) are covered, including advanced and upgraded mature engines. For the steam bottoming cycle, procurement guidelines and specifications incorporate lessons learned from recent plant experience to support technical bid packages.
- Plant design, repowering, and environmental siting reports cover design features, risks, and operating experience of heat recovery steam generators, steam turbines, and electrical generators, as well as integration in an operationally flexible plant design. Emissions control equipment is described, and regulatory trends are monitored. Software provides model-specific O&M cost estimates.

Accomplishments

EPRI's New Combustion Turbine/Combined-Cycle Plant Design and Technology Selection program provides an objective, timely, life-cycle perspective on technology choice and improved plant design.

- Scope covers all 60-Hz and 50-Hz gas turbine models above 20 MW used in power generation.
- Knowledge base covers overall life-cycle costs for project development perspective.
- Component durability information is based on in-depth studies of fleet-leading issues.
- Design provisions are identified for plant operational flexibility and fuel variability.

Current Year Activities

The program R&D for this coming year will focus on advanced gas turbine-based plant designs offering higher efficiency, lower emissions, and improved cycling capability. Specific efforts will include:

- Following current subjects of interest in Combustion Turbine Experience and Intelligence reports
- Identifying new models, capabilities, and features in *Gas Turbine Product Line Design Evolution and RAM-D Issues* reports
- Describing equipment and system design features for improved plant operability and fuel flexibility
- Enhancing maintenance life-cycle costing capability in Combustion Turbine/Combined-Cycle O&M Cost Analyzer software

Estimated 2011 Program Funding

$0.8M

Program Manager

John Scheibel, 650-855-2446, jscheibe@epri.com

Summary of Projects

Project Number	Project Title	Description
P80.001	Experience-Intelligence Reports and Project Risks	Project reports provide concise analysis of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions.
P80.002	CT Technology: Durability, Design and Performance	Project reports cover CT product lines from major OEMs, including design features, related risk issues, and RAM-durability experience. All 50-Hz and 60-Hz models over 20 MW are covered, including advanced and upgraded mature engines.
P80.003	Plant Design, Repowering and Environmental Siting	Project reports cover design features and procurement specifications for commercially available combined-cycle plant equipment such as heat recovery steam generators, steam turbines, electrical generators, and condensers, and include best practices for integration in an operationally flexible plant design. The focus is on significant design improvements that differ from the previous plant buildout. Emissions control equipment is described, and regulatory trends are monitored. Software provides model-specific O&M cost estimates.

P80.001 Experience-Intelligence Reports and Project Risks (067359)

Key Research Question

Technical advances and issues surrounding combustion turbine (CT) and combined-cycle (CC) plants are major factors in new generation decisions, and the impact of those decisions will be felt for years to come. To optimize use of new technologies, plant managers and technical staff need objective, concise knowledge of innovation drivers and industry experience.

CT/CC plant owners and developers are challenged with multiple considerations and objectives in the plant design and selection of technology. A balanced approach to risk identification and cost allocation is essential in the technical development and financial strategy of any new plant project. For example, CT maintenance can cost two to three times the price of the original equipment over the project life. CT owners need to consider major maintenance costs during project development and recognize the technical maturity of particular turbine models. CT/CC project engineers must consider the many elements affecting plant operability and life-cycle costs. In addition, owners and developers need to understand price trends in fuel and electricity markets, and their impact on plant dispatch and profitability. Longer term, owners and operators need to consider the consequences of climate change legislation leading to carbon capture with CT/CC modifications or conversion to alternative fuels such as biodiesel or high hydrogen syngas.

Approach

EPRI collects and analyzes information about current and emerging CTCC designs and cycle configurations, and publishes the results in a series of concise reports supplemented by technical presentations. Topics covered include CT hot-section design features and durability issues, emerging alternative parts suppliers, compressor dependability analyses, and studies on low-NO_X combustion instability studies. Also addressed are the impacts of high-hydrogen syngas and biofuel firing, carbon capture processes, fuel market trends, air-cooled generator issues, and other topics as suggested by members.

In addition, project risk assessment reports help define and quantify risks associated with investment in new CT technologies. Guidance covers decisions about up-front maintenance strategies, such as self-managed maintenance or long-term contracts by the OEM or third parties. A database for CT owners and operators,

INTURB, provides a worldwide directory to facilitate contact with peers to discuss model- and configuration-specific concerns affecting procurement decisions. Special studies examine other aspects of project risk such as the electricity market, natural gas supply, and the timing and impact of carbon capture and credits in the marketplace.

Impact

EPRI reports provide the background and analysis to evaluate various technology and configuration options, allowing program members to:

- Take full advantage of new and existing CTCC plants through concise, current information on new technology developments and issues affecting efficiency, emissions, durability, reliability, and plant operating flexibility to meet dispatch demands
- Mitigate technology and market risk for new CTCC project development through evaluation of alternative maintenance approaches and insights on natural gas and electricity markets
- Gain insights on industry best practices and concerns via a peer-to-peer contacts that facilitate experience sharing and lessons-learned reporting

How to Apply Results

Reports serve as a valuable resource for understanding major components of risk in project development and the use of insurance and maintenance contracts to mitigate a portion of the technical risk. Insights on model maturity and alternative parts suppliers support maintenance strategy planning. Other EPRI studies are employed to address project stakeholder concerns about equipment reliability risks and impacts from changing fuel and electricity market conditions. The INTURB CT owners' directory can help identify other companies and contacts potentially able to provide valuable information and lessons learned from experience with equipment.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
CT Experience and Intelligence Reports: Concise reports in article format provide analysis of subjects of topical interest, including current and emerging CTCC designs and cycles, reliability/durability issues, maintenance strategies, industry trends, and related market conditions. Reports, supplemented by technical presentations and webcasts, are compiled annually into a single report.	12/31/11	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
CT Experience and Intelligence Reports	12/31/12	Technical Update
Project/Technical Risks Assessment	12/31/13	Technical Update

P80.002 CT Technology: Durability, Design and Performance (104059)

Key Research Question

When generating technologies are being selected, the mission requirements (baseload, daily start-stop, or peaking) influence the relative importance of the major competing goals of maximum fuel efficiency, maximum operational flexibility, and minimum technical risk. Gas turbine manufacturers continue to add new and upgraded models to their combustion turbine (CT) product lines. New technology is improving performance, cycling capability and durability of engines with all air-cooled components, as well as those with steam-cooled components. Understanding the design features of each model and their relationship to overall capabilities and possible risks is a challenge. To meet this challenge, project developers and electricity generation owners and operators need an objective, in-depth perspective on technology design evolution, potential risks and benefits, as well as operation and maintenance (O&M) implications of new and upgraded model offerings for all major original equipment manufacturer (OEM) suppliers.

Approach

This project periodically updates a multivolume series of reports covering heavy-duty and aero-derivative engines over 20 MW capacity that are most frequently used in power generation applications. These reports summarize design characteristics of the turbine product lines manufactured by General Electric, Siemens (including Siemens-Westinghouse), Mitsubishi, ALSTOM, Pratt & Whitney, and Rolls-Royce. Each report includes a pedigree matrix detailing design attributes in a standard format. High-risk design features are identified, and relevant technical issues and experience are discussed. Reliability, availability, and maintainability (RAM) statistics are provided for selected models to further identify the overall model maturity and quantify RAM performance. Models of particular interest include more advanced F-, G-, and H/J-class machines, engines suited to highly cyclic duty, and those used for syngas/hydrogen firing. The project seeks additional information about advanced models in design and field verification as opportunities arise.

Impact

- High-quality design assessments and in-service data for high-confidence technology selection and procurement decisions.
- Independently derived RAM statistics for use in evaluations.

How to Apply Results

Members can use these detailed reports to account for site and market conditions and equipment capabilities, as well as identification of technical attributes and associated risks when planning generation additions. In procurement, the information is used to evaluate equipment and select appropriate technology.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Siemens (including Siemens-Westinghouse) CT Product Line - Design Evolution and RAM-D Issues - Update: This report describes the design evolution, features, durability and performance characteristics of the Siemens SGT6-5000F (W501F), SGT5/6-4000F (V94.3A/V84.3A), SGT5/6-2000E (V84.2/V94.2), SGT5/6-8000H, and other engines over 20 MW, including recent upgrades. Current reliability and availability data are included where available. Technical issues affecting maintenance, durability, and reliability are reported. Installed sites and owners are listed.	12/31/11	Technical Update

Product Title & Description	Planned Completion Date	Product Type
ALSTOM CT Product Line - Design Evolution and RAM-D Issues - Update: This report describes the design evolution, features, durability, and performance characteristics of the ALSTOM GT24/GT26, GT13E2, GT11N2, and other engines over 20 MW, including recent upgrades. Current reliability and availability data are included. Technical issues affecting maintenance, durability, and reliability are reported. Installed sites and owners are listed.	12/31/11	Technical Update
Pratt & Whitney CT Product Line – Design Evolution and RAM-D Issues - Update: This report describes the design evolution, features, durability, and performance characteristics of the Pratt & Whitney FT8 and other engines over 20 MW, including recent upgrades. Current reliability and availability data are included. Technical issues affecting maintenance, durability, and reliability are reported. Installed sites and owners are listed.	12/31/11	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
General Electric Aero-Derivative CT Product Line - Design Evolution and RAM-D Issues - Update	12/31/12	Technical Update
Small CT Products for Power Generation and Cogeneration (i.e. Solar, Hitachi)	12/31/12	Technical Update
General Electric Heavy-Duty CT Product Line - Design Evolution and RAM-D Issues	12/31/12	Technical Update
Mitsubishi CT Product Line - Design Evolution and RAM-D Issues - Update	12/31/12	Technical Update
Rolls-Royce CT Product Line - Design Evolution and RAM-D Issues - Update	12/31/13	Technical Update

P80.003 Plant Design, Repowering and Environmental Siting (067360)

Key Research Question

A plant design must satisfy multiple requirements, including increasingly stringent environmental regulations, high efficiency and reliability, and good operational flexibility. Features such as rapid startup and load change, and low-load operation are highly valued in many markets, and some regions may require that plants have "carbon capture-ready" provisions. These features are best considered during the design and procurement process on an integrated plant basis, because retrofits are costly and might not be practical. Repowering an existing site or adapting a gas-fired plant for future coal syngas capability requires additional considerations. Plant developers need highquality information and insight on best design practices and features to be included in their next project. An integrated approach that includes evaluation of plant performance, capital costs, O&M costs, and market conditions on an overall life-cycle cost basis provides the best opportunity for optimized plant design.

Approach

Reports focus on aspects of plant equipment and sub-systems that improve flexibility, durability, and efficiency. Procurement guidelines and specifications incorporate "lessons learned" from the previous buildout of combined-cycle plants. Software provides a framework for estimating operation and maintenance (O&M) costs based on specific CT model and operating duty on a life-cycle cost basis. Other software and studies provide detailed conceptual design and life-cycle cost analysis.

Impact

- Develop more competitive designs and improve equipment procurement decisions by using detailed information on combined-cycle design features, performance, and reliability trade-offs.
- Enhance operational flexibility by identifying and evaluating new plant design features.
- Assess environmental control options on an objective and credible basis.
- Quantify and compare life-cycle costs based on user-defined scenarios.

How to Apply Results

Reports provide information for understanding equipment designs, making procurement decisions, and determining the most effective configurations to meet duty cycles and flexibility requirements. Equipment procurement guidelines can be used directly to support competitive bidding activities. Software quantifies the impact of operating scenarios on O&M costs and provides an overall life-cycle perspective.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Equipment Selection Best Practices and Procurement Guidelines/Specifications: Reports address the specification and procurement of combined-cycle plant equipment, with emphasis on designs and features recommended for improved plant flexibility and durability under rapid startup and cycling conditions. Topics are guided by member interest.	12/31/11	Technical Update
Heat Recovery Steam Generator Procurement Guideline - Update: Updated report incorporates additional guidance for procuring HRSGs with design characteristics for rapid startup and cycling duty applications. It includes updated EPC-style specification for use in HRSG procurement.	12/31/11	Technical Update
CTCC O&M Cost Analyzer, Version Update: This Excel® spreadsheet-based software estimates the O&M costs for combined-cycle and simple-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. This product is shared with Program 79, Combustion Turbine & Combined Cycle O&M.	12/31/11	Software
SOAPP-CT Workstation, Initial Access: State-of-the-Art Power Plant (SOAPP) software provides life-cycle cost perspective on new combustion turbine/combined-cycle plant designs. New Program 80 funders obtain an initial year, single-user license to SOAPP-CT Workstation as part of three-year background access. Future versions are accessed and supported through continuing supplemental project funding.	12/31/11	Technical Resource

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Selective Catalytic Reduction of NOx: Reactor Designs and Procurement - Update	12/31/12	Technical Update
Steam Condenser Procurement Guideline - Update	12/31/12	Technical Update
Gas Turbine/Combined-Cycle Environmental Control Technology and Regulatory Issues Handbook - Update	12/31/12	Technical Update
Steam Turbine and Generator Designs for Combined-Cycle Plants - Update	12/31/12	Technical Update
CTCC O&M Cost Analyzer, Version Update	12/31/12	Software
Cyclic Operation of Combined-Cycle Plants: Designs, Maintenance, Reliability and Cost Impacts - Update	12/31/13	Technical Update
Conversion to Dual Fuel Capability by Addition of Distillate Oil Firing Systems in CT Plants - Update	12/31/13	Technical Update
Repowering Studies and Assessments - Update	12/31/13	Technical Update
Phased Refueling of Natural Gas-Fired Combined-Cycle Plants to Firing Hydrogen Syngas from Coal Gasification with CO2 Capture - Update	12/31/13	Technical Update
Lessons Learned in Startup and Commissioning of Simple-Cycle and Combined-Cycle Plants - Update	12/31/13	Technical Update