



# ADVANCED GAS TURBINES IN COMBINED CYCLE APPLICATIONS



ADVANCED TURBINE SYSTEMS CONFERENCE  
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The Boyce Consultancy



# RELIABILITY AVAILABILITY AND MAINTAINABILITY

## A CASE FOR ON-LINE CONDITION MONITORING

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# GOALS

## NEXT GENERATION TURBINE PROGRAM

15 % OR HIGHER REDUCTION ON O&M COSTS

FLEXIBILITY OF 400 STARTS PER YEAR

IMPROVEMENT OF RELIABILITY,  
AVAILABILITY AND MAINTAINABILITY

MULTIPLE FUEL FLEXIBILITY





# OPERATION OF COMBINED CYCLE POWER PLANTS

NO LONGER BASE LOAD OPERATION

DAILY POWER CYCLING

PLANTS SHUT DOWN OVER WEEKENDS





# 15 % OR HIGHER REDUCTION ON O&M COSTS

- LIMIT DEGRADATION
- OPERATE AT HIGH DESIGN CONDITIONS AT OFF-DESIGN CONDITIONS
- IMPROVE COMPONENT LIFE
- INCREASE TIME BETWEEN MAJOR OVERHAULS





# FLEXIBILITY OF 400 STARTS PER YEAR

- ESTIMATION OF STRESS AND EQUIVALENT OPERATING HOURS
- STEAM TURBINES LIMITING PARAMETER IN COMBINED CYCLE POWER PLANTS





# IMPROVEMENT OF RELIABILITY AVAILABILITY AND MAINTAINABILITY

- TOTAL CONDITION MONITORING
- PERFORMANCE BASED MAINTENANCE
- OVERHAUL BASED ON MONITORING
- SPECIAL LOW NO<sub>x</sub> COMBUSTION MONITORING
- PYROMETER FOR BLADE METAL TEMPERATURES





## MULTIPLE FUEL FLEXIBILITY

- NATURAL GAS AS BASE LINE
- FUEL TREATMENT
- FUEL TRACING AND SPECIAL DESIGN FOR HEAVY FUELS
- ON-LINE TURBINE WASH





# GOALS OF CONDITION MONITORING

- Ensuring High Machine Availability and Reliability
- Maintaining peak efficiency and limiting performance degradation of machine trains
- Extending time between inspections and overhauls
- Optimizing the cycle configuration
- Estimating Availability
- Evaluating scenarios by means of “What If” Analysis
- Estimating maintenance requirements and life of hot section components
- Fault identification by Expert System analysis.





# MAJOR COMPONENTS OF A CONDITION MONITORING SYSTEM

- AEROTHERMAL ANALYSIS
- COMBUSTION ANALYSIS
- VIBRATION ANALYSIS
- MECHANICAL ANALYSIS
- DIAGNOSIS
- TRENDING AND PROGNOSIS
- WHAT - IF





# CONDITION MONITORING

- Present systems serve mostly a monitoring function.
- Monitoring of combustion systems for Low  $\text{NO}_x$  Combustors a very important need which needs to be addressed
- Lifting Algorithms a very important need that remains unfulfilled.





# CONDITION MONITORING SYSTEMS

- Mechanical and Performance Based
- Data Validation
- Aero-Thermal Performance Based Models
- Stress Dynamics with Loading & Temperature
- Rotor Dynamics
- Combustion Stability Analysis
- Trending and Prognostics
- Diagnostics and Expert Systems
- Lifing Prediction
- Optimization Studies





## TECHNICAL ISSUES

- Data Validation
- Development of New Instrumentation
- Development of Lifing Algorithms for Various Hot Section Components
- Development of Diagnostic Matrix
- Development of Optimization Programs for Combined Cycle Plants
- Development of Maintenance Programs based on Condition Monitoring





## DATA VALIDATION

- NEW TECHNIQUES OF DATA VALIDATION
- TRAINING PATTERNS
- NEURAL NETWORKS
- FUZZY LOGIC





## Development of New Instrumentation

- Imbedded Blade Metal Temperature Sensors
- On line Monitoring of Ferrous and Non-Ferrous Particles in the Lubrication System
- On-line Monitoring of Exhaust Gases for Metal Particles
- Long Term Dynamic Pressure Transducers for Combustion Monitoring
- Monitoring Low NO<sub>x</sub> Combustors





## Parameters Effecting Hot Section Life

- Type of fuel.
- Type of Service
- Firing Temperature
- Materials stress and strain properties
- Coatings
- Effectiveness of cooling systems
- Number of starts.
- Number of Full Load Trips.





## Development of Lifting Algorithms for Various Hot Section Components

- Algorithms for Single Crystal and Directionally Solidified Blades
- Algorithms for Combustion Liners
- Algorithms for Various Diagnostics





## Development of Diagnostic Matrix

- Diagnostic For Various Turbomachines
- Design of an Expert System
- Prognostics
- Diagnostics for Rest of Plant Equipment
- Development of Fuzzy Logic Systems with Algorithms





## Development of Optimization Programs for Combined Cycle Plants

- Updating of all Efficiency Curves Based on Data obtained from Condition Monitoring Analysis
- Part Load Optimization of Various Plant Equipment
- Maximizing Efficiency at Off Load Conditions





## Development of Maintenance Programs based on Condition Monitoring

- Performance Based Condition Monitoring Maintenance
- Component Lifing Studies
- Major Inspection Intervals based on Total Condition Monitoring

