



Damage to CCGTs Due to Cyclic Operation
- Operational, Technical and Cost Issues

(Acronym: CCGT Cyclic Operation & Guidelines)

Proposal for a 'Group Sponsored Project' - (GSP)

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By:

European Technology Development

6 Axis Centre

Cleeve Road

Leatherhead, Surrey, KT22 7ND, UK

Tel: + 44 1372 363 111 **or,** + 44 (0)1372 363 112

Fax: + 44 1372 363 222

E-mail: ashibli@etd1.co.uk

www.etd1.co.uk

(This review is a follow-up of an earlier investigation conducted by ETD in 2002 which was sponsored by a number of industries from Europe and North America. Since that study many new developments have taken place in this area including the expansion of the CCGT / HRSG cycling experience worldwide, use of new materials (in particular P91/T91, T23/T24), new designs to incorporate fatigue damage, new R&D findings and so on. This is thus considered as an appropriate time for the cataloguing and critical review of such experience and for producing guidelines and setting benchmarks that need to be followed to reduce damage to components, increase plant efficiency and reduce cost of plant operation and maintenance).

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1. INTRODUCTION TO THE ISSUES INVOLVED

The ongoing privatisation of electricity industry the world over and the ensuing competition and demand by shareholders for higher profits, has resulted in an increasing need to supply power on demand. As a result Combined Cycle Gas Turbines (CCGTs) are increasingly being subjected to load following and/ or two shifting/ cyclic operation. However, cyclic operation can result in new damage types and thus in increased repair and maintenance costs. The aim of this study is to examine the basic causes of these increased costs, with the intention of reducing them through improvements in operating, inspection and maintenance procedures. The study will also investigate recent developments in life assessment procedures, since the long term integrity of CCGT plant is a vital factor in governing electricity prices.

As stated earlier, the trend towards cyclic operation has been stimulated by a number of factors such as deregulation and privatisation which have undoubtedly intensified competition. Relatively small differences in costs and reliability can make a large difference in the station ranking. Many of the early, less efficient, CCGTs are being downgraded to two-shifting. However, once a unit is subject to cyclic operation, reliability can suffer. This means that there is a danger of a vicious spiral setting in so that more two shifting → more unreliability → more two shifting.

Even new CCGT units may need to be subjected to two shift operation prematurely. Power from hydro, wind and solar energy sources cannot be scheduled in the same way as from fossil fuel or nuclear plant. Most combined heat and power systems operate in a base load mode, leaving the peaks to be picked up by large centralised stations. Both trends imply further increase in cyclic operation and load-following in future.

Although many new CCGTs are now designed for two-shift operation, efforts to increase short term reliability are still uppermost in the thinking of the designers. Furthermore, designs are being upgraded in large steps and this can lead to unforeseen problems. The newer units are also presenting a whole new set of materials and component problems. Thus, for example, new higher strength materials (such as P/T91, P/T23 and P/T24) are being utilised without the benefit of long operational trials and weld performance. The differential expansion effects between the newer and the older more established materials result in increased stresses leading to new problems. Furthermore, The read-across from aero gas turbine experience and its transfer to CCGTs is problematic because of scale effects and the completely different temperature regime. Relatively minor increases in gas turbine temperatures have transformed HRSG (Heat Recovery Steam Generators) steam conditions and alternator output. The increased output can have a dramatic effect. Thus, for example, doubling the stress range can reduce the cycle life by a factor of 10.

Thermal fatigue is at its most damaging when the component is operating in the creep range and is subject to a constant tensile load. The higher the temperature the higher the creep rate and creep damage, of course. Fortunately over-temperature operation in CCGT units, in the sense of this being an error on the part of the operating staff, is rare. Nevertheless both the HP turbine stage and sections of the HRSGs in modern machines are well into the creep regime. It follows that creep-fatigue of the classical type, involving gross cracking, can be a major concern. One important issue is that the rates of heating up and cooling down of the turbine blading and HRSGs are very high compared to furnace and superheater structures on

conventional steam plant. Indeed many creep-fatigue failures are now being experienced in the modern CCGTs/ HRSGs.

Failure by simple differential expansion, without the presence of a high static load, will affect combustor cans, leading to cracking and distortion. The oxidation resistant and thermal barrier coatings on combustor cans and blades can also be degraded in this way, the former due to spallation of protective oxide films, the latter due to delamination at the coating-substrate interface. Simple differential expansion may also be a problem in HRSGs even when these are not operating in the creep range. This can be due to poor detailed design, so that high temperature headers are restrained by those operating at lower temperatures. It can also be due to condensate being trapped in some legs of the HRSGs impeding steam flow during start up or shutdown. Here again the problem is due to part of the HRSG being at a different temperature to the rest. Indeed more recently problems have even been found to occur in drainage pots and pipes installed due to operational and design issues.

Waterside issues in CCGT will grow in importance as HRSG temperatures and pressures increase. But as with conventional steam plants, cyclic operation can interfere with water treatment and can result in lowered water quality. And there could be increased problems with corrosion fatigue of economiser tubing, etc. and of stress corrosion of steam turbines. Many CCGT units require good quality steam to control NO_x. Dry air condensers are used, rather than wet systems, since there is less need for copious amounts of water, widening the possible range of locations. Finally, reverse osmosis is being utilised, since this has less environmental impact than ion exchange processes. The impact of operating the water treatment system, during cyclic operation, will be reviewed.

Generator and switchgear can be susceptible to increased fatigue, wear, and other forms of degradation due to repeated stop-start operation and these aspects will be covered in this project.

The whole aspect of the cyclic operation of CCGTs/ HRSGs demands a closer understanding of the issues involved, better monitoring of the plant operation and behaviour of critical components, better plant management systems, a strategy of component inspection and replacement and proper assessment of the costs involved. This project has set out to achieve this.

2. STUDY OBJECTIVES

Specific objective

- To identify the key engineering threats.
- To identify operational constraints.
- To identify engineering and operating costs.
- To set out a strategy for optimising CCGT/ HRSG cyclic operation.

Target Sponsors

- Plant operators with limited experience of cyclic operation of CCGTs.
- Plant operators with advanced experience but who wish to compare their experience with that of others in order to know what is achievable and to set new and higher but achievable targets.

- Experienced operators who wish to use and develop check lists to help improve station practices.
- Operators with limited in-house technical support.
- New owners of CCGTs.
- Plant manufacturers and designers.

General

This project is intended to provide information and data, both technical and financial, on the effect of two-shift and load following operations on key items of plant equipment. The **purpose** of the study is to: a) highlight the main factors that increase the operation and maintenance costs, b) discuss the feasibility of minimising such costs through appropriate technical techniques or management practices, c) increase plant availability, and, d) identify problem areas requiring further developments. The study will also review the prospect of assessing the causes of gradual deterioration in plant performance using existing instrumentation.

The positive and negative aspects of **plant management** will be highlighted. It is recognised at this stage that appropriate *plant monitoring* and *staff training* will be required to ensure good control during start up. Changes to water treatment procedures may be advisable, which can also imply some retraining, particularly if laboratory staff have been downsized.

A number of computerised **on-line data collection and analysis systems** have now been produced to monitor plant operation and damage to components due to cyclic operation. These systems can assist in proper management to limit this damage. Some of the staff involved in this project have been associated, directly or indirectly, with the development of some of these systems and are well aware of others. These systems would thus be reviewed and their usefulness highlighted.

In more **specific** terms the report will discuss the effects of CCGT cyclic operation on:

- thermal fatigue of gas turbines and associated hot section equipment
- thermal fatigue of steam turbine rotors and chests, boiler headers and steam lines.
- stress corrosion and corrosion fatigue cracking of turbine generator end rings, boiler parts, superheater, and reheater pipework and hanger supports.
- oxide scale spalling and enhanced erosion corrosion of plant internals.
- steam turbine back end corrosion and erosion.
- water treatment plant issues leading to increased corrosion problems.
- the need for additional instrumentation.
- staff training requirements.
- development of plant inspection and repair strategies.
- costs associated with CCGT operation (fuel, manpower, engineering, repairs etc.).
- improvements to the plant and the operating procedures to optimise costs.

*This review will recommend a number of **preventative measures** and provide **check-lists** for good engineering practices.*

3. THE KEY ISSUES

The following key issues will be studied and surveyed. (details are in the actual proposal)

- 3.1. Gas Turbine Hot Section Components**
- 3.2. HRSG**
- 3.3. Steam Turbine System Damage by Fatigue/Creep Effects**
- 3.4. Erosion Corrosion of Steam Turbine Equipment**
- 3.5. Effect of Load Cycling on Electrical Components**
- 3.6. Water Treatment and Corrosion**
- 3.7. Increased Fuel and Water Costs**
- 3.8. Staffing and Training**
- 3.9. Research and Development**
- 3.10. Component Repair, Replacement and Cost Analysis**
- 3.11. Plant Improvements and Optimisation of Operational Procedures**
- 3.12. Implementation Plan**

This review will thus be based on the reviewers' own knowledge and experience, published literature, and information accessed from plant designers, manufacturers, operators and technical experts. The intention is to bring together industry, country/ regional studies and plant experience and produce a global report highlighting the problems, issues, challenges, and technical and financial implications. The areas of technology, research and plant management requiring further development will then be highlighted.

5. REPORT STRUCTURE

6. STUDY TIMING
