Damage to CCGTs due to Cyclic Operation

Operational, Technical and Cost Issues

(*Acronym*: **CCGT Cyclic Operation & Guidelines**)

Final Report

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Executive Summary

The on-going privatisation of electricity generation across the world, 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 introduce new types of damage and higher rates of damage, and hence result in increased maintenance and repair costs. In this study, the basic causes of these higher costs are examined, with a view to reducing them through improvements in operating, inspection and maintenance procedures.

Relatively small differences in costs and reliability can make a large difference in the station ranking. Many of the early, less efficient CCGTs have been downgraded to two-shifting operation. 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 cyclic operation leads to more unreliability, which leads to more cyclic operation.

Even new CCGT units may need to be operated in cyclic mode prematurely. Power from hydro, wind and solar energy sources cannot be scheduled in the same way as that from fossil fuel or nuclear plant. Most combined heat and power systems operate in 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.

The principal aims of this study were to collate, critically analyse and review available information and experience on the operation of combined cycle plant under cycling conditions. Specific objectives were:

- To identify the key engineering threats;
- To identify operational constraints;
- To assess the impact on engineering and operating costs;
- To provide guidelines on how to solve the problems associated with cyclic operation.

The information presented in this report has been obtained from ETD's surveys of plant experience, visits to plants, personal contacts, and reviews of recently published literature. 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, including the expansion of CCGT cycling experience worldwide, use of new materials, new designs to incorporate fatigue damage, new R&D findings, and so on. It was thus an appropriate time for the cataloguing and critical review of such experience and for producing guidelines that need to be followed to reduce damage to components, increase plant reliability and reduce cost of plant operation and maintenance.

The report starts with discussion of the background to cyclic operation and then reviews the evolution of CCGT plant (design, construction and materials), and how this has influenced the ability to cycle. Earlier plants comprised a number of low output gas turbines and HRSGs feeding into a single steam turbine which gave good flexibility, whereas modern units consist of a single large output gas turbine and HRSG and there is concern about the ability of such plants to respond to and combat frequency changes in the Grid. Earlier designs of HRSGs were very poor in cycling situations, primarily because of difficulties with condensate removal. Manufacturers are now aware of these problems, but newer HRSG units are larger and operate in the creep-fatigue range, and hence thermal stressing is still a serious concern.

A comprehensive review of the likely damage and maintenance issues under cyclic operating conditions is given in separate sections for the gas turbine, HRSG, steam turbine and electrical equipment. The root causes of problems affecting the GT hot section components are discussed, including thermo-mechanical fatigue of blades and vanes, coatings and environmental effects, and microstructural degeneration. Background information on oxidation-resistant coatings and implications for blade cracking, and thermal barrier coatings and implications for repair and renewal is provided in the appendices.

For the HRSG, there is a discussion of the impact of design, start-up times, materials and weldment issues, and operational aspects including differential thermal expansion and drainage and condensate issues. As well as damage to superheater and reheater components, the implications of cyclic operation for economisers, steam drums, casings and other structures, and valves are considered. There is comprehensive discussion of water treatment and water-side corrosion issues, including flow-assisted corrosion and corrosion-fatigue. Acid dew-point corrosion and stress corrosion cracking on the gas-side of economiser and preheater tubing are also discussed.

The root causes of problems affecting steam turbines, generators and other electrical equipment under cyclic operating conditions are also discussed. For the steam turbine, the main issues are thermal fatigue of thick-section components, and droplet corrosion and environmentally-assisted cracking in the LP turbine.

In a separate section of the report, the results of ETD's survey of CCGT plant operator experience are presented and discussed. This includes feedback on the specific problems of individual plants, maintenance and inspection, modifications to plant equipment and operating procedures, manpower levels and staff training requirements, and other issues.

The report also includes a section on monitoring and inspection techniques for gas turbines, HRSGs, steam turbines and electrical equipment. This section covers monitoring and diagnostic techniques for gas turbines, monitoring guidelines for HRSGs, and vibration monitoring of power plant equipment. Additional background information on the on-line component life utilisation software systems is given in an appendix.

Guidelines on the engineering strategies for dealing with the problems arising due to cyclic operation are presented in separate Tables for GT components, HRSG components, ST components, and electrical equipment. The Tables present a summary of the main problems based on operator experience. For each potential problem, an estimate is given of the likelihood of the problem occurring and the impact that the problem could have on plant availability. The engineering strategies/solutions are provided as guidance for development by users to suit their plant requirements.

Finally, the report contains a section on the costs associated with cyclic operation, including a discussion of manpower costs, fuel costs, loss of potential output, availability and reliability assessment, increased maintenance and plant modifications, and assessment of start-up, maintenance and inspection costs. ETD has developed a 'model unit' approach for analyzing the operating costs of different plants and which can be used for *benchmarking* purposes. This model can also be used for future cost predictions based on the plant historical data, plant size, age and other such information.

This report is intended to be read and used by:

- 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;
- 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.

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APPENDICES