Asset Management Services

Rotating Equipment Performance & Condition Monitoring including Emissions Reporting

Germanischer Lloyd – Service/Product Description
# Rotating Equipment Performance & Condition Monitoring including Emissions Reporting

**Service Title:** Asset Management Services  
**Lead Practice:** GL Asset Management - Cogsys (UK)

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Service Description and Values Generated:

Increased global demand for energy and pressure on supplies of oil and gas has created the need to optimise plant operations, ensure high availability and increase throughput. At the same time climate change and clean air legislation has created additional pressure on owners of process plant and rotating equipment.

From a maintenance perspective the last decade has seen a growth of independent service companies that challenge the traditional relationship between original equipment manufacturers and Operators. Also, condition-based maintenance practices are recognised as mechanisms to increase plant availability.

Germanischer Lloyd (GL) provide technical solutions and product to Owners & Operators of rotating equipment and process plant, our experience includes:

- Industrial Gas Turbines
- Aero-derivative Gas Turbines
- Electricity Generators
- Pipeline / Injection Compressors
- Pipeline / Injection Pumps
- Gearboxes
- Heaters / Boilers
- Steam Turbines
- Electric Motors
- Fans
- Blowers

GL engineers quickly and effectively diagnose equipment faults or reduced performance and have considerable experience implementing fit-for-purpose cost effective solutions for:

- Improving the Performance, Reliability and Efficiency of rotating equipment
- Stationary combustion source Emissions monitoring and reporting
- Protection and Condition Monitoring solutions including technology from Vibro-Meter
GL is independent of original equipment manufacturers and we add value to our Client’s business in the following areas:

- **Improving Reliability & Availability.** Understanding how best to operate equipment and avoid operating outside favourable conditions improves uptime (e.g. high availability and reliability). This can be critical particularly with offshore O&G production where in-built redundancy is expensive and failure of a single machine can result in large production losses.

- **Reducing Costs.** Effective management of operating costs requires knowledge of current efficiencies and energy usage. High energy prices mean that equipment may be operated in ways for which they were not originally designed. Operational efficiency and equipment optimisation are the main factors in managing energy usage and GL solutions support informed decisions to optimise performance in the most energy-efficient way.

- **Capacity Enhancement.** In regions such as the Middle East there is pressure to increase oil & gas production and/or pipeline throughput to satisfy increased demand. GL support Operators with the investigation, analysis and implementation of capacity enhancement programs.

- **Key Discipline Support.** Industry downsizing has resulted in fewer staff being located at oil, gas and power facilities. GL solutions enable remaining experts and specialists to remotely monitor and troubleshoot problems from anywhere in the world using the Internet.

- **Performance Tracking.** Performance limitations have a direct effect on operating costs and the production output. GL online performance monitoring solutions provide continuous tracking of equipment condition, which enables corrective action when degradation is detected.

### Clients and Assets

<table>
<thead>
<tr>
<th>CLIENTS</th>
<th>COUNTRY</th>
<th>ASSETS</th>
<th>PERFORMANCE</th>
<th>EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Grid</td>
<td>UK</td>
<td>22 UK sites, 68 compressors including:</td>
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<tr>
<td></td>
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<td>Alstom/Siemens Cyclone DLN</td>
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<tr>
<td></td>
<td></td>
<td>GE LM2500 + DLN</td>
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<td></td>
<td></td>
<td>Rolls Royce Avon</td>
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<td></td>
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<td>Rolls Royce Avon DLE</td>
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<tr>
<td></td>
<td></td>
<td>Rolls Royce RB211</td>
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<tr>
<td></td>
<td></td>
<td>Solar Titan, SoLoNox</td>
<td></td>
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<tr>
<td>BP Exploration &amp; Production</td>
<td>UK</td>
<td>Schiehallion FPSO</td>
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<tr>
<td></td>
<td></td>
<td>2 x GE LM6000PA &amp; power turbine</td>
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<tr>
<td>Interconnector UK</td>
<td>UK</td>
<td>Bacton Gas Terminal</td>
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<tr>
<td></td>
<td></td>
<td>4 x GE LM2500 + DLE &amp; compressor</td>
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<td>Hydrocarbon Resources</td>
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<td>3 x Rolls Royce RB211 &amp; compressor</td>
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<td>✓</td>
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<tr>
<td>Limited (Centrica)</td>
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<td>2 x GE LM2500 + DLE &amp; compressor</td>
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</table>
- **Emissions Compliance.** GL emissions monitoring solutions are field-proven and recognised as an acceptable and verifiable method of determining and reporting combustion plant emissions such as NOx, CO, O2, SO2, CO2 and unburned hydrocarbons.

- **Emissions Trading.** Emissions trading requires combustion plant Operators to monitor and report their CO2 (and sometimes NOx) emissions against their Government-allocated allowance. GL solutions provide robust and verifiable methods of determining and reporting these emissions.

- **Condition Monitoring.** The experienced application of machine condition monitoring increases reliability by providing early warning of developing problems, before these becomes critical and expensive. GL engineers evaluate existing / obsolete condition monitoring systems, design & commission new solutions and provide static & dynamic vibration analysis of rotating and reciprocating equipment.

- **Machine Protection.** GL design, build and commission protection systems for high-value critical rotating equipment. Our experts provide turnkey monitoring and diagnostic solutions that protect critical plant and assets.

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</thead>
<tbody>
<tr>
<td>Green Stream</td>
<td>Libya</td>
<td>Mellitah Compressor Station, Trans-Med Pipeline 4 x GE Frame 5D &amp; compressor</td>
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<tr>
<td>Al Rusail Power Company</td>
<td>Oman</td>
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<tr>
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<td>✓</td>
</tr>
<tr>
<td>Bord Gais Eireann</td>
<td>Ireland</td>
<td>4 x Solar SoLoNOx Mars 100 &amp; compressor 3 x Solar SoLoNOx Taurus 70 &amp; compressor 3 x EGT/Siemens Tornado &amp; compressor 3 x Volvo DR990 &amp; compressor</td>
<td>✓</td>
<td>✓</td>
</tr>
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a. Performance Monitoring Solutions

GL performance monitoring solutions for rotating equipment utilise measurements from existing instruments that are available from the equipment/site control system. Performance calculations are based on site tests and a performance monitoring system generally includes:

- Online performance monitoring
- Decision support & diagnostic tools
- Reference to the fuel specification
- Corrections to ISO conditions and equipment-specific factors
- Performance calculations for thermal efficiency and power output
- Relationship of fuel gas path performance parameters and power output
- Performance correction factors calculated online to correct power output, heat rate, calculated exhaust flow & temperature

Client-supplied equipment design data can be used to generate correction factors such as:

- Measured ambient temperature, atmospheric pressure & humidity
- Generator efficiency
- Measured air inlet pressure drop
- Measured exhaust pressure drop
- Degradation / Ageing
- Turbine speed

The system continuously tracks and reports equipment changes to predict potential problems and performance issues before these occur e.g. off-condition detection for water washing, loss of power due to faulty guide vane position or change in fuel gas quality. This uses baselines fingerprints, of measured parameters across a range of normal operating conditions, to establish a healthy datum and the tracking of deviations in performance or condition. Baselines are created using manufacturer data or site tests, where the equipment is tested across the full operating range by experienced performance engineers.

Experienced GL engineers can also determine the performance of existing equipment or the effects of engine up-rating, repair or compressor re-wheel / re-bundling. Results can be used to assess manufacturer guarantees, assist site operations, support accurate modelling and provide data to assess any degradation in performance. GL equipment validation and 3rd party witness testing is to recognised industry standards, (including API & ASME Power Test Codes) and includes:

- Independent technical assistance and mechanical health checks during the supply of new or zero-rated rotating machinery
- Supervision of start-up and compliance with specifications and standards
- Gas turbine performance testing
- Compressor performance testing including compressor mapping
- Onset-of-surge testing of compressors to enable anti-surge controller optimisation
- Compressor throughput optimisation
b. Emissions Reporting

GL emissions monitoring and reporting solutions are field-proven on a wide range of combustion plant. Emissions to air from gas turbines, heaters & boilers have a direct correlation with operation of the combustion plant e.g. load, firing temperature, fuel flow & quality, all of which can be reliably and accurately measured by standard package instrumentation. Calibrated emissions models utilise measurements from existing instruments already available in the equipment / site control system and calculate, display, trend & report the emissions of NO\textsubscript{x}, CO, O\textsubscript{2}, SO\textsubscript{2}, CO\textsubscript{2} & unburned hydrocarbons. Multiple gas turbines combustion systems are accommodated including Standard Annular Combustion (SAC), Dry Low NO\textsubscript{x} (DLN) and steam / water injection. The GL method has been operational since 1996, when the UK environmental regulator granted approval to this reporting solution, which has now been implemented as a Best Available Technique (BAT) for European and Middle East Integrated Pollution Prevention & Control (IPPC) emissions compliance reporting.

The key benefits of the GL solution are:

- Recognised by regulatory authorities as a cost effective Best Available Technology (BAT)
- Can be applied to both new equipment and as a retrofit to existing equipment
- Lower capital cost than the installation of in-stack monitoring technology that consist of an exhaust gas extraction/sampling system, gas analysers and calibration gases
- More reliable than in-stack monitoring technology, providing better repeatability and overall uncertainty
- Reduced routine maintenance and lower operational cost than in-stack monitoring technology, which require daily / weekly calibration checks and incur high call-out and replacement costs
- Only requires calibration to satisfy local environmental regulations and following major maintenance e.g. hot section overhaul
- Automatically generates warnings and only requires periodic user supervision
- Automatic emissions reporting to meet local operations and environmental regulations
- Calculates emissions across the entire operating range, including NO\textsubscript{x} reduction technologies
- Can be configured with redundancy (i.e. backup models using alternative engine parameters) to continue calculating emissions if input signals to the primary model fail

GL has extensive experience and an impressive track-record in the specification, engineering design, system build, installation, testing, commissioning and ongoing technical support of emissions reporting systems and our engineers also undertake independent emissions studies, testing and on-site validation.
c. Condition Monitoring Solutions

GL condition monitoring and machine protection solutions include the monitoring and analysis of rotating equipment vibration, temperature, pressure, speed, acceleration etc. Our products and systems comprise the following advanced technology from Vibro-Meter SA of Switzerland:

- Machine protection systems
- Vibration transducers and measurement systems for displacement, velocity and acceleration
- Dynamic pressure measurement systems for gas turbine combustion acoustic sensing
- Temperature, pressure and flow measurement systems
- Cables, connectors, junction boxes, galvanic isolators and signal conditioners
- Electronic interface modules
- Dynamic data analysis software tools

GL condition monitoring engineers will evaluate existing condition monitoring & protection systems and specify the requirements to replace obsolete systems. GL will also design, build and commission turnkey systems that provide static & dynamic condition monitoring & protection of rotating equipment.

GL experts provide tailored monitoring and diagnostic services to minimise the high-cost of unplanned shutdowns. GL provide both onsite and remote healthcare services to evaluate dynamic behaviour and mechanical failures including:

- Vibration investigations including the analysis of signal frequency components
- Diagnostic support, consultancy & studies
- In-situ trim balancing
- Training on vibration instruments and monitoring
- 3rd Party witness testing and validation
- Start-up testing
- Set-up & implementation of condition monitoring systems
- Fault diagnosis using portable and permanently installed equipment
- Remote surveillance of condition and performance

GL also work with Client-nominated specialist suppliers that provide integrated machinery healthcare, overhaul, maintenance and repair services.
a. Case Study - Performance Monitoring

Date: 2003
Customer: Green Stream
Savings: Advanced decision support and contract tracking

The Mellitah Gas Compressor Station, part of the Western Libyan Gas Project, provides compression for the Trans-Mediterranean pipeline from Libya to Italy. GE Oil & Gas supplied the equipment package including 4 x Frame 5D gas turbine-driven centrifugal compressor trains, inter-coolers, after-coolers and waste heat recovery steam generation. The Client, Green Stream - a joint venture between Agip-ENI and the Libyan National Oil Company – appointed a separate operating company for the station and required the installation of a performance / contract monitoring system to:

- Monitor and report performance of the station and each turbo-compressor using Key Performance Indicators of actual performance versus contractual performance e.g. fuel usage, electricity consumed, steam generated and pipeline nominations
- Evaluate and report achievement of contractual targets and overall plant performance
- Provide online thermodynamic performance calculations for each turbo-compressor train and for the overall compressor station
- Simulate different combinations of compressor trains and process duties to achieve the highest energy efficiency for any scheduled gas flow

GL was selected to provide a comprehensive and integrated online solution for plant performance monitoring, verification and simulation of the Mellitah compressor station.

Since the gas comes from a variety of sources, a gas properties module uses online analyser data to accurately calculate thermodynamic properties. For each operating condition the GL performance system accurately models theoretical design curves for the twin barrel centrifugal compressors to calculate: efficiency and power.

The GL solution provides the following benefits to the Green Stream consortium and its Operations and Maintenance service provider:

- Effective remote compressor station performance monitoring of gas supply shipments to Europe
- Contract support and tracking of multi-million dollar deals with financial penalties for under-performance
- Decision support tools that simulate plant operation to implement appropriate measures for achieving optimum efficiency and minimising operating costs
- Key information for implementing preventive and corrective maintenance strategies, including verification of pre- and post-overhaul performance
- Offline decision support tools for ‘what if’ simulation of compressor station capacity under different gas supply / demand scenarios
- Diagnostic and alarm statistics enabling good operations practice plus increased machine availability, increased reliability and a reduction in unplanned shutdowns
The Al Rusail Power Company of Oman selected GL to design, install and commission a Predictive Emissions Monitoring System (PEMS) for their 665MW natural-gas-fired open cycle power station. Environmental permits for air pollution control from stationary sources, issued by the Sultanate of Oman Ministry of Regional Municipalities and Environmental and Water Resources, require power stations to report emissions such as NO\textsubscript{2}, CO, CO\textsubscript{2}, SO\textsubscript{2} and unburned hydrocarbons.

The GL system is a calibrated predictive emissions monitoring system approved in certain countries as a robust and verifiable method of determining and reporting emissions to satisfy Government requirements.

The power plant was commissioned in stages between 1984 & 2000 and in December 2006 was acquired by SMN Power Holding Company Limited to become the first state-owned power generation company to be privatized in the Sultanate of Oman. The plant is located 40-km west of Muscat and primarily uses natural gas fuel however, as a backup diesel fuel oil is stored on site. Electricity is sold to the Oman Power and Water Procurement Company.

The GL system, commissioned in March 2008 obtains process parameters from three different turbine control system types, flow meters on each turbine gas feed line and ambient data from an on-site weather station. The User-friendly web-enabled system is also used to record and display bearing vibration signals and individual turbine power output, by extracting data from energy meters.

The system continuously calculates and reports emissions for the eight GE Frame 9 gas turbines, with one having been modified with a Dry Low NO\textsubscript{X} (DLN) combustion system.
c. Condition Monitoring

Date: 2008
Customer: Bord Gáis Éireann
Savings: Remote condition & performance monitoring

Bord Gáis Éireann (BGE) is wholly owned by the Irish Government. With headquarters in Cork Ireland, BGE own and operate a natural gas transmission network to the highest international safety and operating standards.

The transmission network is monitored 24/7 at Grid Control located in Cork. A SCADA system continuously monitors network conditions including compressor stations. Currently BGE operate 13 gas turbine-driven compressors comprising four units from three different manufacturers. This diversity means that the information presented by SCADA is insufficient for accurate monitoring of compression machinery condition, performance or emissions.

Following the successful implementation of a GL emissions reporting and performance monitoring system for the Beattock and Brighouse Bay compressor stations, BGE decided to expand this web-based system to all engineering departments across the business. This also involved extending the system to include the Midleton compressor station near Cork. Midleton has three gas turbine-driven compressor trains and BGE wanted to monitor both the performance and vibration characteristics of these machines. Therefore, GL expanded the system by adding condition monitoring technology at Midleton, which includes a vibration monitoring & protection system using Vibro-Meter product plus vibration monitoring & analysis software. Midleton is linked to the BGE data network and engineers, including GL, can securely and remotely monitor the performance and condition of these compressor stations using the Internet.

The GL solution currently adds value to BGE business in the following areas:

- Automatic emissions monitoring and reporting per train and per station
- Decision support look-ahead traffic-light dashboard tracking compliance with permitted emissions limits
- Online performance monitoring of compressor trains
- Online mapping of compressor operating points
- Online trending of vibration signals
- Logging and comprehensive analysis of start-up & shut-down transient measurements
- Compressor train condition monitoring
Asset Management Services

- Plant Integrity Management Services
- Pipeline Integrity Management Services
- Production Optimisation (Includes RAM and Gas Processing)
- Dynamic and Steady State Simulation
- Rotating Equipment Performance & Condition Monitoring including Emissions Reporting
- Gas Quality and Interchangeability

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