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PROCEDURES FOR ACHIEVING GREATER EFFICIENCY IN TURBINE COMMISSIONING PROJECTS AT LIQUEFIED NATURAL GAS (LNG) FACILITIES

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Abstract: Liquefied Natural Gas (LNG) is a strategic solution to meet the growing global demand for fuels with less environmental impact, combining high calorific value, low pollutant emissions, and logistical viability. The commissioning of gas and steam turbines in LNG plants is a critical process for ensuring performance, safety, and compliance. This article presents optimized practices that combine intelligent monitoring technologies, process automation, and advanced reliability analysis methodologies.
Keywords: Commissioning; LNG; Turbines; Efficiency; Industrial Automation.

INTRODUCTION

The global LNG market is growing at an average rate of 3% per year (IEA, 2024), driven by the replacement of more polluting sources such as coal and fuel oil. In Brazil, the advancement of terminal and regasification plant infrastructure demonstrates the strategic potential of this resource, while in the United States, projects such as Calcasieu Pass and Plaquemines LNG consolidate the country as a leading exporter (VENTURE GLOBAL, 2023).

The commissioning of motor compressors in these facilities goes beyond a technical requirement: it is a critical factor for the reliability and profitability of the project. Failures at this stage can lead to months of delays, contractual penalties, and millions in losses. This work presents practices and technologies to optimize this stage, ensuring greater operational efficiency and return on investment. Baker Hughes stands out in this segment, offering a wide range of compressors, including centrifugal, axial, and reciprocating compressors, along with gas and steam turbines for oil and gas, power generation, and industrial applications, ensuring high performance and flexibility for various operational challenges.

THEORETICAL FOUNDATION

Commissioning is a systemic verification and documentation process that ensures that facilities and systems are designed, installed, and operated according to the owner's intentions (NEY; FORTES, 2017). In gas turbines, based on the Brayton cycle, and steam turbines, based on the Rankine cycle, commissioning specifics include fine control adjustments, functional tests, and integration with monitoring systems.

Reliability theory, especially through the Weibull distribution, is widely used to model failures in turbomachinery (ZOTTI; VALANDRO; IZQUIERDO, 2023). The application of RCM (Reliability-Centered Maintenance) enables preventive strategies based on the criticality of the equipment.

Advances in Industry 4.0, such as fiber optic sensors and IoT integration, enable continuous monitoring of critical parameters (LIMA; MERABET JÚNIOR, 2025), while cyber-physical systems optimize real-time data control and analysis.

METHODOLOGY

This study is a qualitative, exploratory research project developed through a literature review, with the aim of identifying, analyzing, and systematizing existing scientific production on the topic. The search was conducted in the SciELO, Google Scholar, and Web of Science databases using descriptors such as commissioning; LNG; turbines; efficiency; industrial automation. Publications in Portuguese and English that were directly relevant to the study objectives were included. Works that were not peer-reviewed or that were not relevant to the proposed theme were excluded. The selected material was submitted to a full reading and descriptive and comparative analysis, allowing for the y organization of information into thematic categories to identify convergences, divergences, and gaps in the literature.

MONITORING AND CONTROL TECHNOLOGIES

The use of smart sensors to measure vibration, temperature, pressure, and chemical composition allows for the early detection of operational deviations (LIMA; MERABET JÚNIOR, 2025). SCADA systems integrated with IoT platforms enable remote monitoring and predictive analysis. Two-way digital communication and self-diagnosis increase operational reliability. Monitoring in LNG plants has evolved into a cyber-physical approach, in which sensors, control systems, and analytical algorithms work in an integrated manner:

- **Smart sensors and fiber optics:** these enable the detection of variations in temperature, pressure, and vibration with high precision and reduced latency (LIMA; MERABET JÚNIOR, 2025). Vibration sensors coupled with turbogenerators have enabled predictive adjustments that have reduced unscheduled downtime.
- **IoT integration and LoRa networks:** long-range communication (LoRaWAN) enables continuous monitoring of turbines and compressors in hard-to-reach areas, reducing the need for on-site inspections.
- **SCADA and DCS systems:** GE Cimplicity and Siemens PCS7 allow real-time visualization and control of critical variables, with data redundancy to increase reliability.
- **Predictive analytics and machine learning:** Algorithms trained with historical failure data—such as those based on deep neural networks—are already used to predict failures in bearings and rotors.

The combined application of these technologies ensures proactive response to problems, reduced MTTR (Mean Time to Repair), and increased turbine availability.

COMMISSIONING PROCEDURES

The commissioning of turbines in LNG plants must follow a structured roadmap, covering three main phases:

- **Pre-commissioning:**
- Verification of mechanical, electrical, and instrumentation integrity.
- Visual and endoscopic inspection of rotors and combustion chambers.
- Electrical insulation and continuity tests, low voltage (ABNT NBR 5410, 2019).
- **Commissioning itself:**
- Functional tests under no load and partial load.
- Calibration of critical instruments for pressure, temperature, and flow.
- Safety tests, such as fuel supply failure simulation and emergency shutdown (NEY; FORTES, 2017).
- **Assisted operation:**
- Continuous monitoring of parameters and fine control adjustments.
- Comparative analysis between design data and actual measurements.
- Knowledge transfer to the local team, ensuring the continuity of best practices (ZOTTI; VALANDRO; IZQUIERDO, 2023).

Practical example: at the Plaquemines LNG plant (USA), a relatively *low-cost* plant, anticipating loop check tests and automating data collection reduced the total commissioning time for motor compressors by 15% (VENTURE GLOBAL, 2023).

FEASIBILITY AND DIMENSIONING STUDIES

The feasibility analysis must consider technical, economic, and environmental aspects:

Proper sizing of the turbine-compressor assembly to meet the maximum expected demand, without under- or oversizing.

Evaluation of CAPEX and OPEX with probabilistic scenarios for fluctuations in gas prices and maintenance costs.

Integration of cogeneration systems, using waste heat to power steam turbines and improve overall efficiency (MOURA; D'ANGELO, 2015).

The use of thermodynamic simulations, such as those performed in MATLAB/Simulink, allows different configurations to be compared and energy gains to be estimated prior to implementation.

EFFICIENCY OF OPERATIONAL AND MANAGEMENT PROCEDURES — DATA AND CASES FROM THE US

Commissioning efficiency is not just technical: it is management, governance, contractual planning, and operational adaptability. In the United States, recent experience with large LNG export projects provides clear lessons on practices that increase (or reduce) efficiency, with direct impacts on schedule, revenue, and reputation.

Efficiency can be maximized through thermodynamic cycle optimization, the use of data-driven predictive maintenance, and the application of optimization algorithms. Reliability management should focus on indicators such as MTBF (Mean Time Between Failures) and MTTR (Mean Time To Repair).

US projects have intensively adopted modular design (independent blocks/trains) and staggered commissioning—which allows production and export to begin with parts of the plant still under commissioning. This practice reduces time to first revenue and dilutes financial risk, but requires interface governance and strict segregation procedures between areas in operation and areas under construction. The case of Calcasieu Pass (Venture Global) illustrates this: the terminal began producing LNG between 2021 and 2022 and loaded its first commissioning cargoes while other units were still being released for operation.

Public data shows significant impacts when management allows cargoes to be exported during commissioning. In Venture Global projects (Calcasieu Pass and Plaquemines), the strategy of selling cargoes before the commercial operation date generated significant revenue during the commissioning phase, but also caused contractual tensions and customer questions about delivery reliability. Financial and journalistic reports indicate that the practice generated billions in revenue (added value to operations), while projects faced cost overruns and contractual disputes that increased the actual cost of commissioning.

The pressure to generate revenue quickly can affect operational and environmental controls if commissioning is rushed or poorly managed. For example, investigations and reports pointed to reliability issues and environmental impacts at Calcasieu Pass during its commissioning phase, with public criticism of emissions and unstable operations leading to regulatory and reputational repercussions. These factors show that "pure" efficiency (faster = better) can become inefficient when it translates into fines, rework, and corrective costs.

Based on the US examples, it is possible to summarize management practices that actually increase efficiency during commissioning:

- Interface governance: formal structures to manage boundaries between construction/commissioning/OP (clear handover criteria and "frozen") — reduces rework and integration failures. (evident in DOE reports on modular project progress).

- Layered commissioning planning (loop checks, detailed pre-commissioning, "dry runs") and test automation — reduces re-execution time and increases acceptance data quality.

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Project / Location	Commissioning start year	Time to first commissioning load	Commissioning strategy	Estimated pre-commercial revenue	Key efficiency gains	Key challenges/risks
Calcasieu Pass (Venture Global) - Louisiana	2021	~12 months after start of modular unit construction	Modular + phased commissioning	US$ 3-4 billion (estimate based on sales during commissioning)	Anticipated revenue; performance validation on individual trains, use of automation in loop check	Customer complaints about reliability; regulatory questions; environmental impact
Plaquemines LNG (Venture Global) - Louisiana	2024	~10 months after partial operations begin	Modular + commissioning cargo sales	Not officially disclosed; estimated in billions based on volume and spot price	Reduction of time-to-cash, partial operation while construction continues	Contractual disputes over deadlines and deliveries; pressure for stability
Caeron LNG (Sempra) - Louisiana	2019	~8 months after phased commissioning by train	Phased commissioning by train	Not disclosed; used to stabilize production and calibrate systems	Greater control over ramp-up; integration with initial export	Weather delays; technical adjustments to compressors

Comparative table of metrics and cases

Source: Author.

- Well-defined commissioning cargo contracts and clauses — to avoid disputes between developers and buyers over the commercial status of deliveries; ambiguous clauses have led to disputes in recent projects.
- Continuous monitoring and transparent communication with agencies maintains pressure for compliance and facilitates controlled partial releases (according to public progress reports).

Cases such as Cameron LNG show that the use of commissioning charges is an established practice to stabilize production and validate performance before the final commercial date — when well conducted, it reduces time-to-cash without compromising performance; when poorly managed, it results in regulatory impact and correction costs (e.g., additional expenses and legal/regulatory pressure in some recent US projects).

Based on US data and cases, it is recommended to: standardize acceptance criteria; automate test data collection and storage (ensuring auditability and traceability); negotiate contracts with clear definitions of commissioning positions; maintain regular reporting to regulatory agencies; incorporate sustainability and emissions metrics into the acceptance checklist. These practices balance commercial speed with operational integrity, reducing the likelihood of rework, fines, and loss of reputation.

CONCLUSION

The success of an LNG project depends on effective commissioning, supported by advanced monitoring technologies such as smart sensors, remote monitoring via IoT, predictive analytics, test automation, regulatory and normati y protocols, and strategic management providing a proactive response to potential failures, reducing repair time and increasing turbine availability.

In addition, detailed commissioning planning, governance of interfaces between construction and operation, clear contractual clauses on commissioning loads, and transparent communication with regulators are critical to success and risk mitigation during this critical phase. Practical cases show that significant gains can be achieved with modular planning and automation, but also that environmental and contractual risks can compromise results. Constant updating of practices, based on lessons learned and technological evolution, will be decisive in maintaining competitiveness in the global energy market.

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GLOSSÁRIO

COMMISSIONING (turbines): systematic process of ensuring that a turbine (whether steam, gas, or hydraulic) is designed, installed, tested, and operating correctly in accordance with project specifications and requirements.

DCS: Distributed Control System is a more integrated and complex control system designed to manage continuous and complex processes within a single facility or industrial plant, distributing control functions among multiple controllers.

FPSOs: floating unit used in the oil and gas industry for the production, storage, and transfer of hydrocarbons, such as oil and natural gas, produced in subsea fields.

GE Cimplicity: a robust and flexible HMI/SCADA (Human-Machine Interface/Supervisory Control and Data Acquisition) system used to monitor and control industrial processes.

IoT: acronym for "Internet of Things," refers to a network of physical objects that have sensors and software, allowing them to collect, process, and share data with each other over the internet.

LoRa: short for "long range," is a long-range, low-power wireless radio frequency technology.

LoRaWAN: Long Range Wide Area Network is an open, low-power wireless network protocol used to connect Internet of Things devices in long-range networks. Based on LoRa radio technology, it allows battery-powered devices to communicate through gateways with a central server.

MATLAB: numerical computing software and programming language developed by MathWorks.

SCADA: Supervisory Control And Data Acquisition, a platform supervision and data acquisition system.

SIMULINK: a graphical programming environment developed by MathWorks, integrated with MATLAB, used to model, simulate, and analyze systems.