

GT2005-68129

REVOLUTIONIZING GAS TURBINE MAINTENANCE IN LNG SERVICE

Stephen G Raymer
BP
Houston, TX 77079
USA
raymersg@bp.com

B Fred Evans
BP
Houston, TX 77079
USA
evansbf@bp.com

Charles A Gautschy
BP
Houston, TX 77079
USA
gautscca1@bp.com

Anthony S Andrich
BP
Houston, TX 77079
USA
andricas@bp.com

ABSTRACT

Atlantic LNG has developed a proven method for LNG turbine maintenance, which will revolutionize the industry. Over the life of Atlantic's 4-Train facility, this method will reduce planned downtime by over a year. This paper details the innovative approach that the authors took to reduce Atlantic LNGs first major gas turbine overhaul from 29 days to 23 days, and the second major overhaul from 23 days to 18 days, with the ultimate goal of a 12 day turnaround (TAR).

Atlantic LNG will soon begin a cycle in which a major overhaul is required approximately every 6 months as we cycle through our fleet of 26 Frame 5s. Using Gantry System technology, the company will be able to achieve a 50% reduction in downtime, which equates to approximately 1 year of additional production over the life of the plant.

INTRODUCTION

Atlantic LNG Company of Trinidad and Tobago is a joint venture company in which BP, BG, Repsol, Tractabel, and NGC are all shareholders. Atlantic cools and liquefies natural gas for export by tanker to the US and Spanish gas markets. Atlantic's LNG Plant is located in Pt. Fortin, Trinidad, where there are 3 Trains operating, and a 4th under construction. Train 1 began operations in 1999, Train 2 in 2002, and Train 3 in 2003. Trains 1-3 each have six Frame 5 Gas Turbines driving refrigeration compressors, while Train 4 has eight. Each Train is designed to be able to operate at reduced rates (only half of the Gas Turbines operating) to allow continued production during scheduled maintenance. When Train 4 starts operations

in 2005, Atlantic will have 26 Frame 5D Industrial Gas Turbines to operate and maintain. The scheduled maintenance for these machines is an operational necessity and drives the availability of the entire plant.

THE PROBLEM

Traditional Overhaul Method Duration

The gas turbine drivers that Atlantic LNG uses for refrigeration compression are General Electric (GE) Frame 5D's. These are large, industrial type gas turbines, in contrast with the smaller and lighter "aero-derivative" type. The maintenance cycle for these machines drives the overall plant availability, because they are designed to undergo a periodic major overhaul lasting 29 days every 48,000 hours.

The traditional overhaul method for industrial gas turbines requires an in-place disassembly and inspection of the entire gas turbine- both the high pressure (HP) and low pressure (LP) modules (Fig. 1). This is a time and labor-intensive activity, requiring a large amount of lay-down area for parts, operations and maintenance personnel sharing the same work area in an operating plant, and an extended exposure of maintenance personnel to the operating plant. This method, with its focus on speed and downtime, increases the temptation to take shortcuts during the exposure of the internals to the environment. For the Atlantic layout, a "best in class" overhaul using this method takes 29 days.

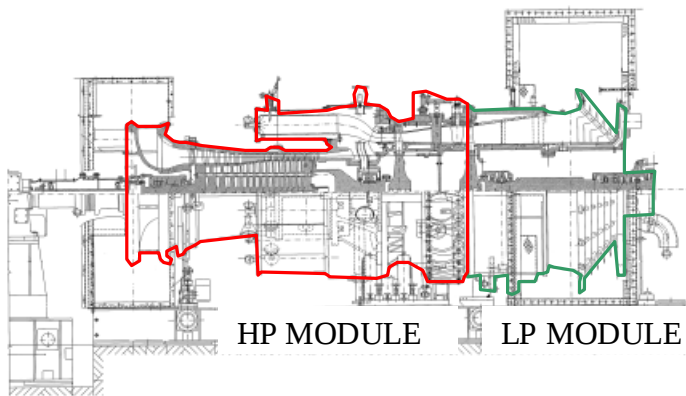


Figure 1: Frame 5D Schematic

Overhaul Duration Drives Plant Availability

LNG critical path maintenance activities differ from most other industrial gas turbine applications- for example a major refinery overhaul usually is focused on equipment other than the gas turbine drivers, such as catalyst replacement, furnace repair, boiler and pressure vessel inspection, etc. For an LNG plant, the availability of LNG production is directly related to the time required to service the gas turbines. In fact, over half of Atlantic LNG's scheduled downtime for the life of the plant is solely due to turbine overhauls.

Any LNG plant's objective is to maximize LNG production. The first step towards maximizing production was to design parallel gas processing paths within a train so that reduced rate production could be continued during the maintenance cycle. Atlantic LNG's parallel operation allows 3 concurrent overhauls while the remaining 3 turbines continue to operate. The next step towards maximizing production was minimizing scheduled downtime; and reducing the overhaul duration is the most effective way to do that.



Figure 2: In-Place Maintenance of a Frame 5D

Additional Drawbacks of In-Place Maintenance

In place disassembly of a gas turbine inside an operating LNG facility increases the risk that a less than optimal repair will be achieved as opposed to a repair that takes place in a shop specifically built to overhaul gas turbines. Furthermore,

repair of the modules in a controlled shop environment separates the impact of the overhaul duration from LNG production.

The standard in-place repair is also exposed to additional risks associated with replacement parts availability, and the potential for addition repairs over and above what is normally necessary to refurbish the gas turbine. Should an unexpected need for a part, or an unanticipated repair operation arise, the additional time required to locate and obtain that part will, in all likelihood, directly reduce LNG production.

The most important drawback of in place overhauls is the additional exposure of maintenance personnel to the operating plant. It is much safer to perform the work required in a shop environment.

THE SOLUTION

The Frame 5D Becomes Available

Atlantic LNG's Train-1 was designed prior to advent of the Nuovo Pignone Frame-5D. Atlantic's original Train-1 Frame-5C units produced approximately 15% less power than the Frame-5D. Since LNG production is closely approximated by power, a fast-track Turbine Upgrade Project was initiated to retrofit Train-1's six Frame-5C refrigeration drivers to newly available Frame-5D units.

The Frame-5D gas turbine utilizes a Frame-6 axial compressor configuration. Conversion necessitates removing the Frame-5C HP casing components (approximately 50 tons) and replacing them with a new casing/components located within the same skid footprint. Atlantic's 10-ton overhead crane was designed for traditional, in-place maintenance (Fig. 2). As noted in "the problem", traditional casing/component removal requires timely disassembly and parts removal using the 10 ton and supplemental cranes.

Development of the Modular Approach

During Train-4's design, a driver study explored reducing downtime associated with aero-derivative core-engine swaps versus in-place Frame unit overhauls. This study produced LNG specific life-cycle economics showing saved engine-swap downtime could easily justify a small fleet of spare core-engines. The Upgrade Project recognized the approach was not philosophically limited to aero-derivatives and initiated studies with Bechtel, Nuovo Pignone, and JR engineering to investigate modular engine replacement potential for large industrial frame gas turbines.

Two frame-engine modular swaps methodologies were developed; one using an external long-reach crane, and another using gantry cranes and special module transporters. The long-reach crane method required an extremely large crane and considerable compressor-building roof and infrastructure removal. This required working/lifting over live equipment during and extended downtime. Also, the open roof would expose all turbine/compressor work to the daily rain showers in the area.

With the gantry system concept, turbine modules are lifted by portable gantry towers and placed onto special transporters (Fig. 3). The four gantry towers telescope up and down, and can also travel axially along the turbine on special tracks.

Between opposing towers there is a cross beam; traveling back and forth on this cross beam are carts which hold the lifting hooks. The module is lifted, slowly moved out perpendicular to the skid, and lowered onto a transporter. The transporter has 12 articulated wheels that can rotate 180 degrees. A central control panel provides hydraulic power via umbilical cables to all gantry lift components and hydraulic transporter wheels. The transporters then maneuver the turbines around the refrigeration compressors and drive to the edge of the elevated compressor deck for removal by an external crane.



Figure 3: New HP Module on Transporter (background); Empty Transporter being positioned for removal of old HP Module (foreground)

Selection of the Gantry Technology

Ultimately the gantry/transporter system was selected. Extensive life-cycle economics were conducted with sensitivities on modular versus traditional conversion. Results indicated downtime savings were sufficient enough to economically justify the conversion.

The Upgrade Project worked with Nuovo Pignone to secure a lump-sum, turn-key contract to upgrade 6 Frame-5C turbines to Frame-5D's in two separate 23-day TAR's. This represents a 6 day reduction from each traditional, non-modular upgrade turn around and is 2 days less than that used in modular-approach life cycle economics. The Upgrade Project consulted with schedule risk consultants and TAR challenge experts in order to develop statistical probability of the 23-day schedule success. In addition, a full-scale mock test using job modules, gantry's, transporters, and 3-D clashes was conducted. Ultimately probability of 23-day success was considered "P-50" (a 50% chance of success). The definitive test would come in the form of two Upgrade Project Turnarounds: one planned for September of 2003, and the other in April of 2004.

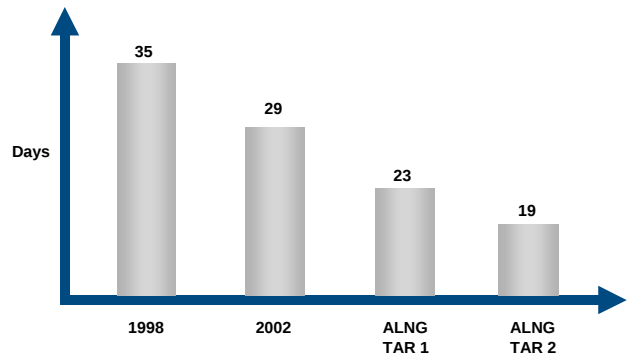


Figure 4: Days Required for 5C to 5D Conversion

PROOF: THE GAS TURBINE UPGRADE PROJECT

Replacing the First 3 HP Modules

In September 2003 the authors used this Gantry System to simultaneously overhaul 3 out of the 6 Train 1 turbines in only 23 days (Figure 4). In this first overhaul, only the HP Modules were swapped out: the LP Modules were repaired in place. It was not known at the time if it was possible to replace an entire LP Module. The S curve for the first shutdown showing the duration and major milestones is included as Figure 5

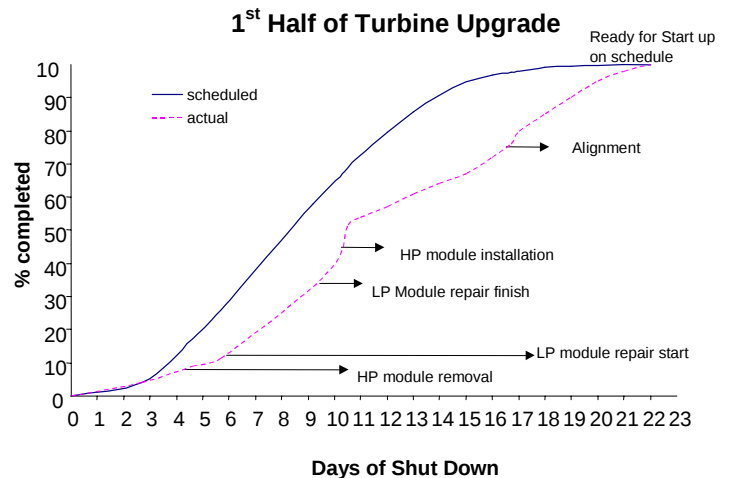


Figure 5: Actual vs Planned Progress for 1st Phase of Gas Turbine Upgrade Project

This first test of the gantry system was a great success. The HP Modules were removed and reinstalled as planned (Fig. 6 and 8). The machines started up with no issues. However, the standard (split casing in place) overhaul of the LP module (Fig. 2) took 4 days. At this point the team began to consider the possibility of using the gantry system to replace that entire unit as well.



Figure 6: Gantry Removal of HP Module

Train 3 LP Module Repair

In the period between the two shutdowns, Atlantic LNG became aware of a defect in the LP Modules of two Frame 5Ds on Train 3. They had to be repaired. At this time, the decision was made to remove and replace these defective modules using the gantry system so that they could be repaired in the shop rather than in the operating plant. This was also a complete success. The project team was now confident they could save the 4 days that it took to repair the LP module in place by replacing the LP module with a new unit, and incorporated that learning into the 2nd phase of the Gas Turbine Upgrade Project.

Replacing the Second 3 HP and LP Modules

In 2Q 2004, the remaining 3 turbines were overhauled in 18 days – a further 5-day improvement. Again, there were no issues on startup. The S curve for the second shutdown is Figure 7.

2nd Half of Turbine Upgrade

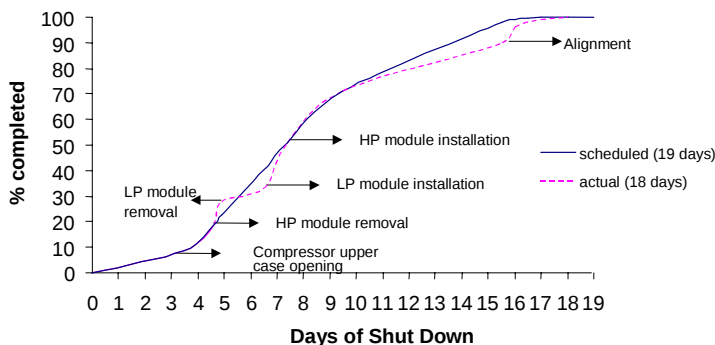


Figure 7: Actual vs. Planned Progress for 2nd Phase of Gas Turbine Upgrade Project

It is important to recognize that this improvement occurred in an event where every activity is scheduled, detailed, scrutinized and optimized, and every hour accounted for. This truly represents a step change improvement.

Safety and Schedule Performance

The safety statistics and schedule performance are shown in Table 1. It is important to note that a significant amount of

work was also done on the compressors during these shutdowns.

Gas Turbine Upgrade Stats	Duration (days) Plan / Actual	OSHA Recordables	Man-Hours
1 st Shutdown (Figure 4)	23 / 23	0	112195
2 nd Shutdown (Figure 6)	19 / 18	0	87800

Table 1: Gas Turbine Upgrade Safety and Schedule performance

THE IMPACT

A Step Change Reduction in Downtime

Atlantic LNG will soon begin a cycle in which a major overhaul is required approximately every 6 months as we cycle through our fleet of 26 Frame 5Ds. Using Gantry System technology, we plan to achieve an impressive 12-day target for normal major overhauls. This represents a 50% reduction in downtime; which over the design life of the plant equates to over a full year of additional production.

In addition, this approach increases the expected risk weighted production through decreased overhaul duration and increased quality of repair. Our sparing philosophy now has the potential to reduce our expected LNG losses if we have a catastrophic failure, since we have spare modules.



Figure 8: Gantry Installation of HP Module

Local Economic Benefit

Because of Atlantic's geographic location, a dedicated repair shop specifically designed for maintenance of the turbine modules is being constructed at Pt. Fortin. This favorably impacts the local economic development, improves Atlantic's control and oversight of the repair process, and reduces transportation cost and risk.

Future Train Design

Atlantic is considering designing new Trains around this modular replacement strategy, building in the infrastructure in the initial facility design to reduce the overhaul duration to the minimum achievable.

Maintenance Strategy and Economic Impact

Table 2 illustrates the overhaul frequency which Atlantic LNG will require to support the 4 trains currently operating or under construction. Atlantic is designing its long-term service agreement around the modular approach, as it will require between 1 and 3 turnarounds every year starting in 2006. The impact of saving 12 days at every turn-around is easy to determine. Over the life of the plant, this new approach developed by Atlantic LNG represents 380+ days of production, 60+ cargoes, and over One Billion Dollars at 2004's average Henry Hub price.

Schedule of Module Replacements for Trains 1,2,3,4

Year	Train 1	Train 2	Train 3	Train 4	Total	Turn-Arounds
2005					0	
2006		6			6	2
2007	3		6		9	3
2008	3				3	1
2009				8	8	2
2010		6			6	2
2011	3		6		9	3
2012	3				3	1
2013				8	8	2
2014		6			6	2
2015	3		6		9	3
2016	3				3	1
2017				8	8	2
2018		6			6	2
2019	3		6		9	3
2020	3				3	1
2021				8	8	2
Total	24	24	24	32	104	32

Table 2: Atlantic's Modular Replacement Schedule

CONCLUSIONS

Atlantic LNG has proven that Frame 5 Gas Turbines can be overhauled as modules- and further that this modular approach represents a considerable time savings over the traditional method. This saved downtime equates to significant incremental production and returns for our shareholders. The gantry system is safe, portable, and easy to use. Every LNG plant (or any other service) that depends on Industrial Gas Turbines for production can benefit from applying this method.

ACKNOWLEDGMENTS

The authors would like to acknowledge the following groups who helped develop and execute the modular approach: Atlantic LNG Management, JR Engineering, Nouvo Pignone, Bechtel Equipment Operations, and the Paramount Co. of Trinidad and Tobago.