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INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE

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Large Turbine, Central Power Generation on Offshore Production Facilities

by

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Career

- 2005- Currently serves as Marketing Director for Rolls-Royce Energy's Global Aftermarket organization, "Customer Service Business"
- Prior to 2004- Held increasing levels of responsibility within the marketing and sales organizations at Rolls-Royce affiliated companies.
- Prior to 1990- Worked offshore with Unocal, and in the underground storage department at Southern California Gas.

Education

- MBA, Ohio University, Athens, Ohio
- BS Petroleum Engineering, Marietta College, Marietta, Ohio

Personal

- Married with two children (ages 10, 6)
- Lived in (at least 3 months):
    - Pennsylvania
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Abstract

In addition to determining the type of structure that will support an offshore production facility (ie fixed or floating type, semi-sub or FPSO, GBS or tension leg, etc.), facility developers must determine the basic design for energizing the facility. Energizing the facility refers to the method in which power is generated and delivered to the production equipment. The continuum from which to choose the energizing method has at one end, multiple, small energy sources that are spread throughout the facility, each one dedicated to a particular service. At the other end of the continuum is a large energy source that generates power for the entire production facility and then distributes the power to each of the various production services.

During the previous five years, Rolls-Royce has observed a trend towards large, central power generation / distributed electricity among offshore production facilities (the concept is heretofore referred to as the large turbine concept). This trend has resulted in robust sales of the company's gas turbine products that are rated at or above 26MW. The large turbine concept enables facility developers to recognize advantages that include better fuel efficiency, lower environmental costs, lower maintenance costs, increased production, and lower module costs. This paper is a case study that illustrates these advantages.

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Case Study

The focus of this case study is a hypothetical offshore production facility. The performance specifications for the production facility are given in figure 1. The facility will be a fixed leg platform. It will produce approximately 240,000 BPD of oil and 540 MMSCFD of associated gas. The gas will be subjected to three stages of separation for removal of hydrocarbon liquids and water. The liquids, natural gas, and crude oil will be exported from the production platform to an onshore receiving terminal.

Production

API Gravity	Oil Production, BOPD	Gas Production, MMSCFD	Water Gas / Water
30-44	240,000	540	515

Separator Design

Gas Stream	Source	Suction Pressure, psi	Discharge Pressure, psi	Flow Rate, MMSCFD
High Pressure	First stage separator	498	1209	17
Medium Pressure	Second stage separator	213	498	35
Low Pressure	Third stage separator	43	213	540

Figure 1- Performance Specification for Production Facility

For any given production facility, the service that requires the greatest amount of power is often gas compression. Gas compression for this case study represents about 70% of the power load. The balance of the load is represented by the liquid export pumps (16%), and by general utilities (14%). This case study will compare two alternative options for the gas compression duty. The source of electrical power for the export pump and the utility duties will be considered unchanged between the two options and therefore will not be considered in this case study.

Development Options

This paper will consider two development options for the three-stage separator / compression process shown in figure 1. The options are:

Option 1- Small turbine option (<=15 MW Rating, ISO)
Option 2- Large turbine option (>=26 MW Rating, ISO)

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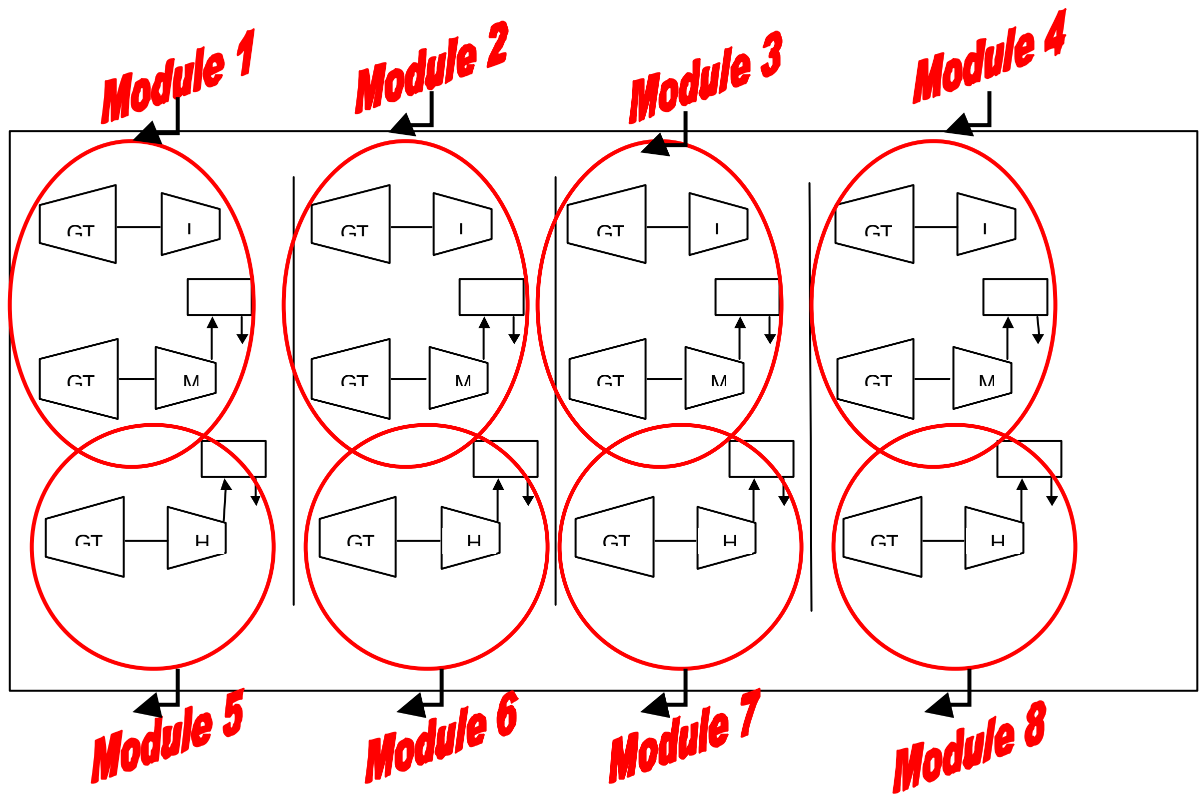

Figure 2- Option 1, Small Turbines

Option 1 is representative of a traditional equipment configuration, established 20-30 years ago. The configuration utilizes a single gas turbine dedicated to each stage of compression within this multi-stage compressor application. Factors related to the production process (such as a need to accommodate variable flow rates between services) can justify this traditional approach.

Modern compressor designs now enable multiple services to be achieved within a single compressor casing. This modern approach will be utilized for Option 2.

Option 1 utilizes 4 x 33% compression trains. Each train consists of:

- 1 x 313 kW Gas turbine / compressor for the low pressure service
- 1 x 469 kW Gas turbine / compressor for the medium pressure service
- 1 x 7320 kW Gas turbine / compressor for the high pressure service
- 2 x Gas intercoolers
- 4 x Inlet / discharge scrubbers
- 2 x Single lift structural steel modules to contain the equipment and for mounting on the platform deck space.
- 2 x Control rooms / panels

In total, Option 1 utilizes 12 x gas turbines + 12 x compressors + 8 x coolers + 16 x scrubbers + 8 x production modules + 8 x control rooms / panels.

Option 2 utilizes a configuration of production equipment that is popular today, having been proven reliable on many recent offshore developments. Modern equipment such as multi-section compressors, mechanical variable speed drives, and large gas turbines have evolved over time to provide unsurpassed reliability / availability. For example, a single RB211 gas turbine provides a reliable source of power that may be distributed to multiple compressors requiring up to 33 mW (ISO). The RB211 can start electrical loads as high as 14 mW, and it has demonstrated reliability statistics in excess of 99%.

The option 2 configuration can be seen in figure 3. Option 2 of this case study will utilize a large gas turbine for generating power centrally, then the power will be distributed to each of the three compressor trains. In summary, Option 2 utilizes 3 x 50% compression trains + 2 x 100% power generation trains.

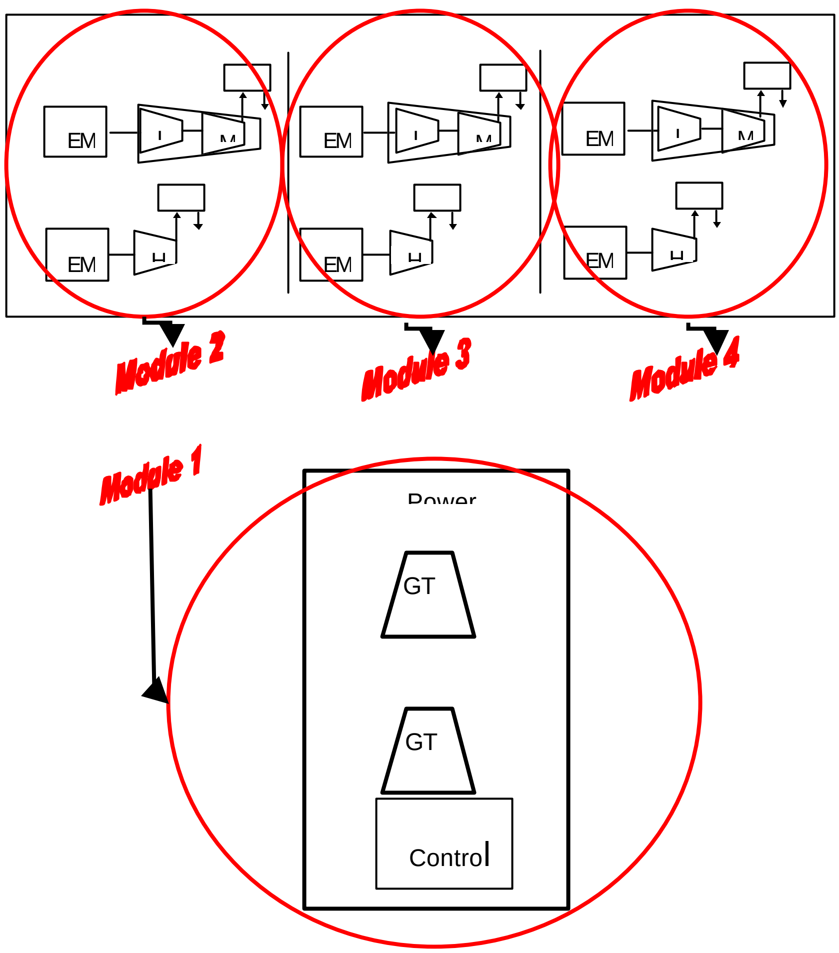

Figure 3- Option 2, Large Turbines

For Option 2, each train consists of:

Compression
- 1 x 1,417 kW mechanical variable speed drive / 2 section compressor for the low pressure and medium pressure services
- 1 x 10,589 kW electric motor / compressor for the high pressure service
- 2 x Gas intercoolers
- 4 x Inlet / discharge scrubbers
- 1 x Single lift structural steel module to contain the equipment and for mounting on the platform deck space.
- 1 x Control room

Power Generation
- 2 x 29,000 kW RB211 Gas turbine generation packages
- 1 x Central control room
- 1 x Single lift structural steel module to contain the equipment and for mounting on the platform deck space.

In total, Option 2 utilizes 2 x gas turbines + 6 x mechanical variable speed drivers + 6 x compressors + 6 x coolers + 12 x scrubbers + 4 x single lift modules + 4 x control rooms / panels. The mechanical variable speed driver is a device that uses the principles of hydrodynamics to vary the speed of a centrifugal compressor when driven by a fixed speed, electric motor. It offers the advantages of high reliability / availability, without the additional space required by a variable frequency drive. The mechanical variable speed drive is also field experienced in offshore production service.

Life-Cycle Comparison of the Options

A comparison of the two options was made with respect to:

1) Total capital expenditure (CAPEX) for the equipment, completely packaged within single lift modules.
2) Equipment weight relative to its impact on the cost of platform structural steel.
3) Equipment dimensions relative to its impact on required platform deck space.
4) Operating and maintenance cost over a 20-year horizon.
5) Fuel cost over a 20-year horizon.
6) Annual production capability at the facility design point.

The large turbine, central power generation option enables a savings of over $85,000,000 for this offshore production facility. The detailed savings are shown in figure 4.

	Option 1	Option 2	Dollar	Per-Cent
Module Savings	$80,140,000	$75,280,000	$4,860,000	14%
Weight Savings	912,068 kg	797,862 kg	$239,418	1%
Area Savings	921 m^2	729 m^2	$413,000	1%
Gas Turbine Overhaul Savings, 20 yr present value	$6,648,869	$2,690,733	$3,958,136	11%
Sub-total			$9,470,554	26%
Fuel Cost Savings, 20 yr present value	$70,075,927	$43,568,563	$26,507,364	74%
Sub-Total Savings			$35,977,918	100%
Other Savings:				
Environmental			Reduced Exhaust Emissions	
Additional Production (+99% vs 98.6% availability)			$49,248,000	
Total Savings			$85,225,918	

Figure 4- Savings from Option 2, Large Turbine Concept

Discussion of the Results

Over $9 million of the savings afforded by the central power generation concept (Option 2) are due to savings in the capital and maintenance expenditure categories. Nearly $5 million of the savings are attributed to less costly topsides modules. Simply put, Option 2 requires fewer modules than Option 1. The modules of Option 2 are lighter and require less deck space than the modules of Option 1. The weight and area advantages of Option 2 permit savings in the cost of steel used for the platform supporting structure and its deck space. Using evaluation factors of $1900 / ton and $200 / ft^2, Option 2 offers an additional savings of +$600,000, compared to Option 1.

Nearly $4 million (present value) in savings comes from the repair and overhaul of only one operating gas turbine in lieu of nine (the repair and overhaul analysis did not consider the stand-by spare gas turbines). Over a twenty-year period, the large turbine, central power generation option requires only nine (9) scheduled overhaul events, whereas Option 1 requires fifty-four (54) scheduled major overhauls.

Over $26 million (present value) of the savings afforded by the large turbine, central power generation concept is due to the savings in fuel cost. Modern, large gas turbines such as the RB211 provide simple cycle efficiencies near 40%, whereas, the smaller turbines associated with Option 1 offer efficiencies in the 28-35% range.

Another way to look at the efficiency advantage is to consider its environmental impact. The large turbine option is performing the same duty as the small turbine option, while burning less fuel. The lower fuel burn translates to less exhaust emissions that are harmful to the environment and to the air we breathe. Exhaust gas constituents such as nitrogen oxides and carbon monoxide are greatly reduced with the large turbine option.

Increased Production at Design Point

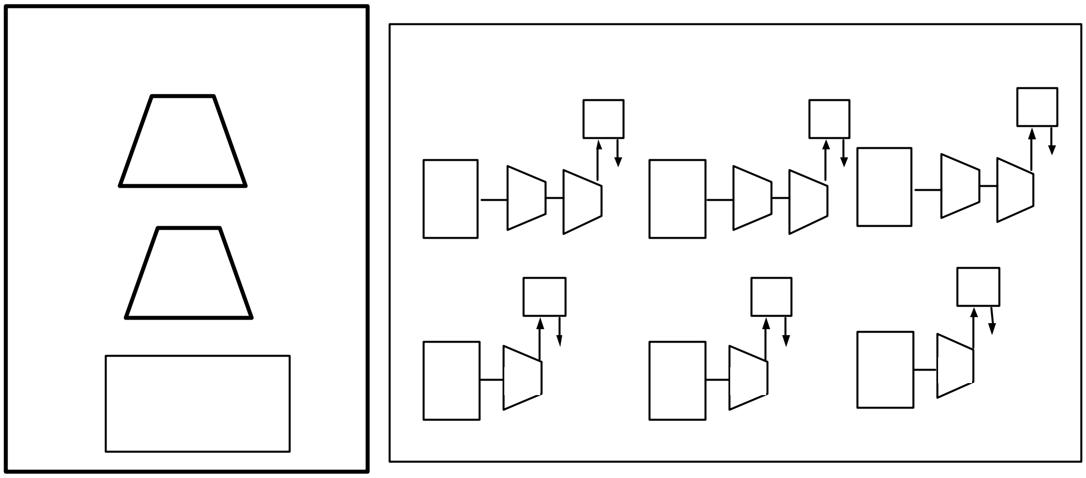

Figure 5- Train Components for Option 2

Figure 5 identifies the individual train components for the large turbine option. The components are assembled into a production facility comprised of 2 x 100% power generation (gas turbine) + 3 x 50% compression trains (mechanical variable speed drive). Train availabilities are assumed as 98.36% and 99.53% for the gas turbines and the mechanical variable speed driver units, respectively. Each of the 50% compression trains consists of two electric motor / mechanical variable speed compressors in series. Thus the availability for each two-unit compressor train is the product of the unit availabilities (99.53*99.53 = 99.07). The availability of the power generation train is simply the 98.36% value mentioned above. Applying a statistical distribution to the power generation and the compression trains and correcting for the train availabilities, the large turbine option can be shown to have a total facility availability in excess of 99% at the design point.

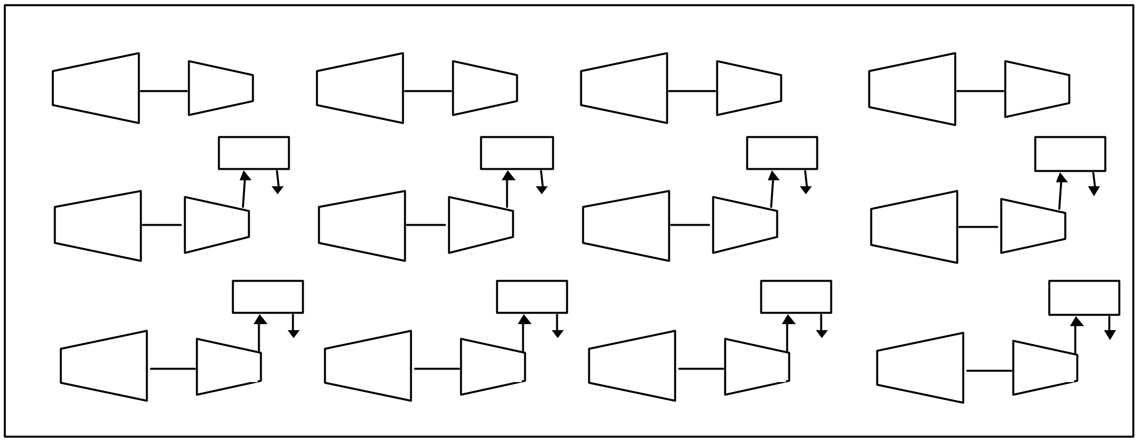

Figure 6- Train Components for Option 1

Figure 6 identifies the individual train components for the small gas turbine option. The components are assembled into a production facility comprised of 4 x 33% compression trains (gas turbine driven). As with the large turbine option, 98.36% availability is assumed for each gas turbine unit. Each of the 33% compression trains consists of three gas turbine driven compressors in series. Thus the availability for each three-unit compressor train is the product of the unit availabilities (98.36 * 98.36 * 98.36 = 95.15). Applying a statistical distribution to the compression trains and correcting for the train availabilities, the small turbine option can be shown to have a total facility availability of 98.6% at the design point.

The higher availability of the large turbine, central power generation production facility equates to approximately 5 days per year of additional production. This 240,000 BOPD facility could yield an additional $49,248,000 per year (at $45 / bbl) with the large turbine option! This is true at the design point. Facility developers must determine the importance of evaluating production at the design point versus production at off-design point conditions. For the present case study, an evaluation at reduced flow rates could diminish the production advantage of the large turbine option.

Conclusion

This paper has demonstrated the advantages offered by modern, fuel efficient large gas turbines in central power generation service for offshore production. A case study was presented using the Rolls-Royce RB211 large gas turbine and advantages equated to over $85 million. The advantages are due to:

*Savings in both the quantity and size of offshore modules
*Savings in platform deck space
*Savings in structural steel due to reduced weight on the production deck
*Savings in gas turbine repair and overhaul cost
*Savings in fuel gas consumption
*Savings (un-quantified) in environmental cost due to reduced exhaust emissions
*Increased production at the facility design point

The advantages of the large turbine, central power generation concept have been widely accepted by numerous operators. Offshore facilities have been constructed in both shallow and deep waters using the concept. Following is a partial list of recently developed offshore production facilities using large turbines (>26 MW).

Offshore Production Facility	Operator	Production BOPD	Number of of Rolls-Royce Trains Operating	Spare	Total
P43	Petrobras	146,000	3	1	4
P48	Petrobras	127,000	3	1	4
Sanha	ChevronTexaco	100,000	3	1	4
Belanak	ConocoPhillips	100,000	7	0	7
White Rose	Husky	100,000	2	1	3
East Area Gas	Exxonmobil	Gas	5	0	5
Sable	Exxonmobil	Gas	1	0	1
Block 18	BP	200,000	4	0	4
P52	Petrobras	180,000	3	1	4
P51	Petrobras	180,000	3	1	4
			34	6	40

Figure 7- Recent large turbine production facilities

Figures:

References:
1. "Are all electric platforms viable in the Gulf of Mexico", Stan Beaver, Charles McDonald, Donald Voltz, IEEE Paper number PCIC-2002-15,.
2. "Mechanical variable speed drive / axial centrifugal compressor can provide a cost effective solution for pipeline duty", Bryan Kendig, Gas Electric Partnership, February 4-5 2003.

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