“Cookin’ with Gas”

LIGHTER AND SIMPLER GAS TURBINE PACKAGES

Some very special yachts have used gas turbines (GT): *Ecstasea, Detroit Eagle, WallyPower, Nobody* and only a few others. However, despite wide aerospace, military ship and plant usage of GTs along with the burgeoning use on (admittedly mostly diesel electric) cruise vessels, these highly – though it must be said, very narrowly and specifically – efficient power sources have yet to gain wide acceptance and use, especially in production yachts. Inspired by the recent application of a new approach on a Pershing 115, Tom Keefer of T3 Automation penned the following. He makes his case for the wider use of GTs and explains what advances have been made in Alarm Monitoring and Control to make use of their truly turn-key (or push-lever) operation. He further explains a new gearbox development which slims down by a third over previous tubbier non-yacht-specific designs.

A TF50 GT engine is generally used on 30- to 60-metre yachts as part of a CODAG (Combined Diesel And GT package) to deliver higher speeds than possible with conventional, all diesel systems. A new Pershing 115 was recently delivered that uses the GT as a boost engine (bottom pages 130 and 133 sister ship, top left and right page 132) driving a fixed, non-steerable, water jet which adds an additional 20 knots of top-end speed when engaged. Vericor Power Systems, the OEM for the TF Series engines, showed a full size mock-up of the TF marine package in their booth at the 2007 Genoa show. This display included the new lightweight reduction gear from ZF Specialty Marine and a simulated version of Vericor's new integrated control system. This package was developed in conjunction with packager Diesel Center SpA of La Spezia, Italy and T3 Automation and had just been successfully sea-trialled on the Pershing 115, producing a 55-knot top speed.

Background

There are many considerations when specifying a propulsion system. Size, weight, fuel consumption, complexity, and of course available power are all important. The most common approach is to select a standard marine high-speed 4-stroke diesel. Recent advances in common rail diesel technology have made this a solid choice amongst builders, but what about other alternatives?

Another option is the GT engine. The term "gas" does not refer to the type of fuel, but rather hot gases that are produced by the combustion of fuel. Such hot gases are produced by compressing incoming air in the compressor section of the engine. To this compressed air, fuel is introduced and the mixture is burned in the combustor section. The resulting "gas" is then forced through a series of blades on the output shaft of the engine. Rotational energy is developed as the gases push on these blades with tremendous force. The output shaft is connected to the input shaft of a reduction gearbox prior to driving a conventional waterjet or propeller shaft. Although a GT can operate on a variety of fuels, they are generally configured to run on standard DMA marine diesel.

Turbines are in use all over the world. Helicopters, turbo-prop aircraft, military hovercrafts, fast ferries, and countless industrial applications are a testament to the reliability and usefulness of these engines. Turbine engines generally have longer TBO (Time Between Overhaul) and are much smaller in size than a diesel engine of the same power. This is mainly due to the nature of the combustion process. A typical diesel engine operates at extremely high internal pressures, and thus the "shell" of the engine requires a large block which adds considerable weight. In contrast, the internal pressures in a gas turbine are comparably low. Overall this yields a much higher powered density; for example, a 5,600 HP gas turbine may only weigh 730 kg, that is 7.6 Kw per kilo without the reduction gearbox!

One key operational difference between a gas turbine and a diesel is rotational speed. A typical diesel will operate at about 2300 RPM, whereas a GT will be around 16,000 RPM. Therefore, the reduction gearbox for a GT application is generally larger and heavier than its diesel engine counterpart to account for this difference. Although operating at much higher RPMs, the turbine generates very little noticeable vibration due to the lack of counter-acting forces such as piston and crank movements.

Challenges

Since turbine engine installations are not common in the yacht community, some builders have been reluctant to embrace this technology. A perception exists that a turbine is too complex for a yachting application or is only for very unusual projects. Predictably, every yacht has different requirements for the propulsion system since builders attempt to offer unique advantages to their customers. Variations in gearbox design, air inlets, water jet types, or user interface requirements require some level of modification to the standard design.

Coming Together

Vericor are sole suppliers to the marine industry of the TF Marine GTs. They realised that improvements were needed in the overall installation package. Although their core business is to provide engines, they recognised the need to be more involved in the overall system design for projects to be successful to both the end user and the builder. Although TF engines have been used on a variety of projects in the past several things have changed in the last couple of years leading to the recent Pershing launch and the propulsion package shown at Genoa.

First is ZF's lightweight GT gearbox (page 133, top right). As well as making RPM reductions well in excess of those demanded by an internal combustion engine the TF engine is specifically designed to be mounted on the gearbox without additional heavy support structures. This new gear was conceived when ZF concluded that not only were GTs under-utilised in the mega-yacht field but also existing gearboxes were far too heavy and were being designed for vessels other than high-performance yachts. ZF changed all that by first employing finite element analysis to achieve an optimised gear case design. Then an epicyclic gear set was used for the first stage of reduction and rolling element bearings were used throughout to reduce the amount of lube oil required.

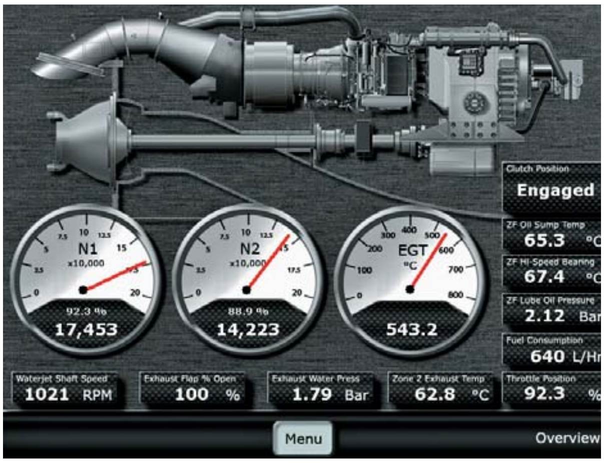
All of this allowed ZF to meet their target weight of 2,100 kg for the first production units, a full 1,000 kg lighter than the gearboxes used previously. The ZF gear employs a hydraulically actuated multi-disc clutch with an optimised engagement control designed to allow the turbine boost power to be engaged smoothly and seamlessly. Extensive testing and sea trials of the Pershing proved that worked in practice.

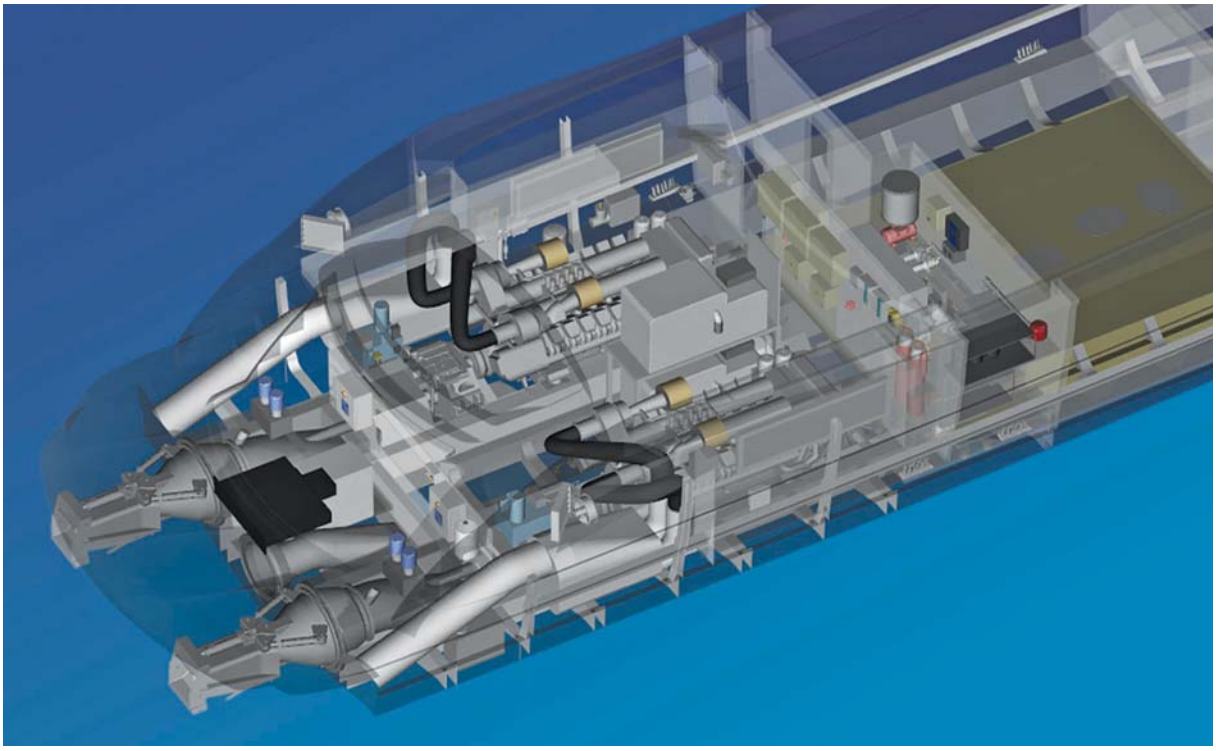
ZF says that the gear can also be produced to allow a small diesel input in a combined diesel or gas turbine CODOG (Combined Diesel Or Gas turbine) option. The possibility of combining two or possibly three turbines COGAG onto a single gearbox also exists.

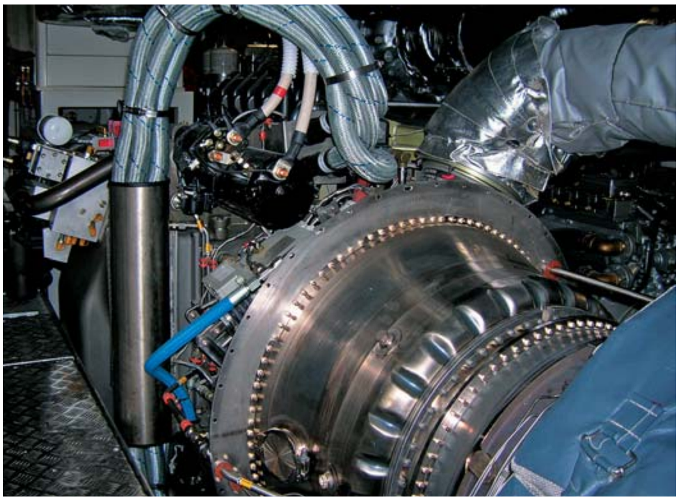
Control System Improvements

A key development to broaden turbine use especially in production yachts like the Pershing was an integrated turbine control panel or ITCP. Most machinery rooms are cluttered with various control boxes, displays, black boxes; therefore, Vericor decided there was another opportunity for improvement by combining several control functions into a single unit. Previous yacht applications of GTs generally had at least two control systems. One was dedicated to exclusively running the GT and was provided by the turbine manufacturer. The other control system managed the gearbox, fuel, and exhaust equipment and any unique ship-specific equipment.

For this development, Vericor enlisted T3 Automation, a marine automation systems integration company. T3 had not only supported previous GT projects such as the WallyPower 118, a triple TF-50 application, and







M/Y *Nobody*, a twin TF-40 Mangusta, but also has over 20 years' experience in large-scale industrial automation applications. A multi-disciplined team comprising Mr Joe McMurry from Vericor Power Systems, Mr Lorenzo Previsani from Diesel Center, SPA , and Tom Keefer, from T3 Automation began the eight-month task of merging the turbine and ship automation requirements into a single package.

The decision to use common, off-the-shelf, automation components that met marine certification was made in lieu of developing a custom control system. Many naval applications have already embraced this departure from custom controls due to the proven reliability of these components and ease of troubleshooting and repair. Cost factors and worldwide availability are other advantages. Start-up sequences were developed to synchronise the turbines sub-systems such as the gearbox, fuel, inlet and the exhaust, as well as verifying signal integrity and alarm processing. Completely automated system start-up and operation is handled via the supplied throttle assembly and touch panel display. Pressing the start button initiates the turbine start-up sequence; 30 seconds later, the engine has reached idle and the gearbox is ready to clutch-in.

The ITCP also coordinates the operation of the turbine and the gearbox as never before. Hi-speed logic precisely manages the turbine engine power levels and multi-disk clutch operation of the ZF gearbox to provide an additional level of equipment protection if the need arises to clutch out immediately. The system monitors key propulsion system parameters and provides automatic protective warning messages and system shutdown in the event of abnormal operation. Tremendous effort was taken to ensure that the alarm warning and shutdown system was understandable by the most basic of users. Preemptive warning and fault messages were designed to clearly indicate the problem which would lead to a much greater chance that the on-board engineer could correct the problem.

Installation Improvements

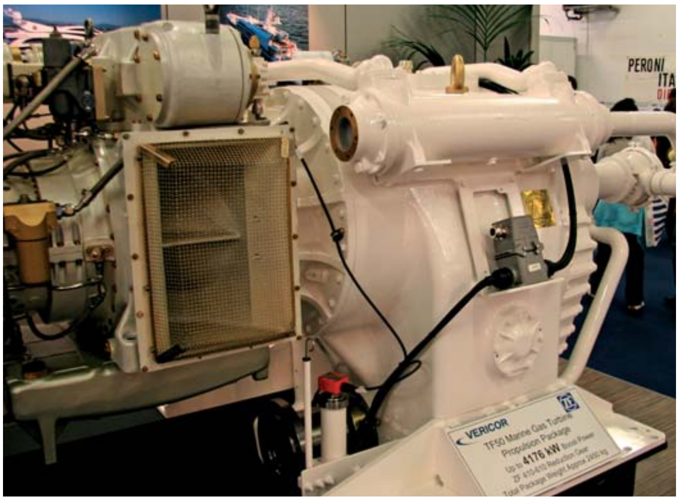
Individual wiring harnesses were developed to connect each of the sub-systems such as the gearbox, exhaust and fuel delivery systems. This greatly simplified the installation and commissioning process. The end result was a three-day checkout for the entire system compared with two weeks on a previous Pershing project.

User Interface

"The system has to be usable. If it is too complicated no one will want to use it!" explained Engineer Lorenzo Previsani, from Diesel Center. "When I get into my car, I turn the switch on and drive it. I should not have a thousand lights and buttons telling me information I don't need to know". And so from this concept, the team set about developing the most automated control system to date for the TF gas turbine package while maintaining a philosophy of keeping it simple. This meant devising an operator interface to allow basic operational and alarm/emergency functions all from a single control lever (opposite top left) – analogous to diesel engine control. Detailed graphical displays and mimics were developed for the touch panel to present the user with relevant information while keeping the layout simple and intuitive. In the event of an alarm, streamlined fault messages ensure the user understands the problem (see images on page 130 middle left and right) and can choose the appropriate corrective action rather than leaving it to an automated system. This makes unnecessary shutdowns less likely than in earlier installations. Of course should the operator not respond to the alarm, underlying safety interlock systems are still in place ensuring protection of the GT.

User Comments

How does the crew react to CODAG propulsion? It's not just that it offers a very fast 55 knots, but also that



with the two main diesels at maximum power, simply pushing the turbine throttle forward adds an additional 20 knots in less than eight seconds. “Having this ‘extra gear’ is a huge advantage,” explained the ship’s captain, “The turbine boost option allows the ship to quickly reach many destinations that would require an early morning or overnight departure. With this kind of speed, we can target more destinations within a regional area, allowing the owner to do more in less time. Another important advantage is that we now have the speed to potentially outrun approaching weather if need be.”

Adaptations

According to Vericor, one of the most common questions is whether a gas turbine can be operated over a wide power range, similar to a conventional diesel. The answer of course is yes. For example, there are several gas-turbine-only-powered yachts which do all their maneuvering and low-speed operation on the gas turbines. It’s just an engine after all, driving a water jet; it just doesn’t use pistons to do it. (*However, GTs do work efficiently at a very specific maximum power and are rather inefficient at other speeds thus the justification for CODAG, multiple GT and GT powered generators in a DE ship – Ed.*)

Future

The simplified control, installation and lighter weight seem to be convincing builders. Vericor have three new TF50 installations planned for 2008. The company also hosts an annual conference in Cannes with the aim of bringing together most of the Med’s TF gas turbine operators for an informal day of operational tips, training and discussions.

Tom Keefer
T3 Automation

Opening photo: istock.com; other photos supplied by Pershing, Tom Keefer and Tork Buckley

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Sister ship to Pershing 115