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# Turbomachinery INTERNATIONAL

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# Features

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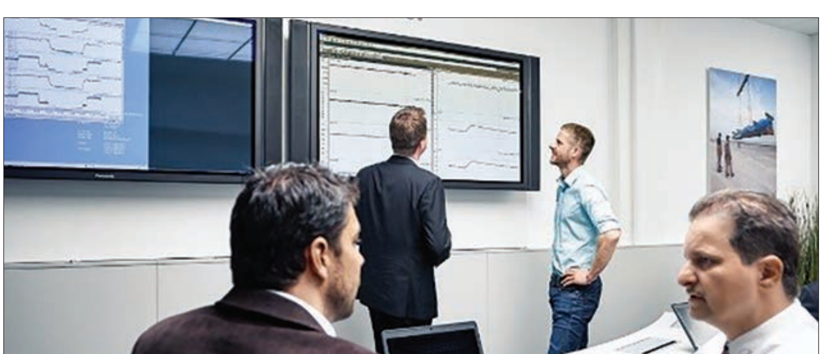
***Cover photo: Operator harnessing Siemens SPPA T3000 controls to manage turbomachinery assets***



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A headline like *Controls Revolution* may meet with the accusation that we have gotten caught up in the hype. As turbomachinery controls have not markedly changed overnight, what is the revolution? It's about how those controls tie into a much larger ecosystem. That includes plant-wide, fleet-wide, company-wide and smart grid-integrated supervision of turbomachinery.

*Drew Robb*

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*Amin Almasi*

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This is part one of a two-part series examining the goal of 65% combined cycle efficiency. Based on the current rate of progress, adding another 4% efficiency over the next ten years is ambitious and may not be credible.

*Rainer Kurz & Klaus Brun*

# BEYOND THE DIGITAL HYPE

A headline such as "Controls Revolution" may be met with the accusation, in some quarters, that we have gotten caught up in the hype. In and of themselves, turbomachinery controls have not markedly changed overnight. So what is the revolution? It's about how those controls tie into a much larger ecosystem.

The control of turbomachinery assets is moving beyond the supervision of the turbine operator. Everything is marching in the direction of higher-level control. That includes plant-wide, fleet-wide, company-wide and smart grid-integrated supervision of turbomachinery.

Plants want to coordinate the actions of their many systems. This requires connectivity. With that comes a necessary relinquishing of some turbine operator control. If a call is required to tell the GT operator to begin firing up the machine, and that means he sends an assistant to open some valves, check fuel quality and hit the start button, opportunities could be lost in what is our volatile power marketplace.

Moving up the hierarchy, organizations with multiple generating facilities want to determine which assets are providing power over which time periods. They need to be able to quickly coordinate the starts, stops and maintenance intervals of multiple plants simultaneously. They may even need to switch things around at a moment's notice.

Here's an example to explain why: A European power provider had one of its facilities down for scheduled maintenance. Another of its plants in the region was also taken down briefly for unscheduled maintenance. Out of the blue, a gas turbine plant owned by someone else went off the grid. Prices spiked. For a two-hour window, a MWh could be sold at an exorbitant rate.

The power producer couldn't respond fast enough to meet the need and the opportunity was gone. But had it been able to plan more efficiently, and coordinate its maintenance actions more effectively, it would have earned enough during those few hours to run one plant for the rest of the year.

The smart grid, too, is another wave of centralized control that is changing the way plants operate. Interests outside of the organization may dictate when power is to be ramped up or down. This will not only be done for monetary gain, but also to maintain grid stability. A greater degree of system control from beyond the organization is likely to come into play here.

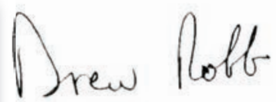
The goal of one unified grid, harmoniously operating like a single organism is unlikely ever to be achieved. But that is the direction we are heading. Technologies such as the Internet of Things (IoT), wireless, new sensors, the cloud, digitization, open systems and more, are the enablers of this vision.

There are those, of course, who will complain that the old controls were better than the latest batch of digitized tools. In some cases, they may have a point.

Let's use a home appliance analogy. Old analog refrigerators, for example, were known to run for decades. But modern computerized fridges tend to break down every couple of years due to their healthy appetite for motherboards. But there are benefits to the latest models in terms of better temperature control, energy consumption and general efficiency.

Moving back to the power plant, the benefits of new controls are far less frivolous than getting a text message that your milk is about to go bad. We are talking here about materially boosting profitability, streamlining fleet maintenance, a more stable grid, and reducing downtime, to name a few.

Of course, there will be mishaps and missteps. But the end game is coming whether plant personnel like it or not as the benefits appear to outweigh the risk. Whether you call it a revolution in turbomachinery controls or not, major change is inevitable. ■




DREW ROBB
*Editor-in-Chief*

Operating companies throughout the world met in Milan, Italy for ETN's user group dedicated to the Industrial RB211 aeroderivative gas turbine

## First RB211 user group event

In May, representatives from Industrial RB211 operating companies throughout the world met in Milan, Italy. This was the first European Turbine Network (ETN) meeting of an engine-specific user group dedicated to the Industrial RB211 aeroderivative gas turbine.

ETN is a non-profit association bringing together the entire value chain of the gas turbine (GT) technology community. Through cooperative efforts and by initiating projects, ETN seeks to optimize GT research and technology development, and promote environmentally sound gas turbine technology with reliable and low cost operation.

In Milan, industrial RB211 users discussed GT issues with original equipment manufacturers (OEMs), independent service providers (ISPs) and the research & development (R&D) community. Major fleet owners, such as BP, Shell, Total, Statoil, ExxonMobil and National Grid of the UK, participated in the gathering. Over 150 industrial RB211 engines were represented at the event. "Users found ETN's two-day meeting valuable," said Christer Björkqvist, ETN Managing Director.

During the RB211 event, users exchanged experience and established a dialog with Siemens, TransCanada Turbines and RWG (a joint venture of Wood Group and Siemens for the maintenance, repair and overhaul services for Siemens and Rolls-Royce industrial aeroderivative gas turbines.) The purpose of the meeting was to define and develop solutions to prioritized operational issues and requirements. The organizers dedicated a full day to interactive sessions between Siemens representatives and the user community.

"The ETN User Group Meeting proved to be a valuable networking tool and the stepping stone for a united user front to bring attention and closure to lingering engine problems and the sharing of best practices," said Oscar T. Moguel, Operations Technical Programmatics Machinery Advisor, ExxonMobil (Angola).

Industrial RB211 users around the world are encouraged to join the group. The goal is to establish a strong, independent and knowledgeable user community that can exert a major influence on future engine developments.

***www.etn-gasturbine.com***

## Improved 7FA parts

PW Power Systems (PWPS), a group company of Mitsubishi Heavy Industries, is offering enhanced 7FA.03 parts by maximizing the turbine capacity and reducing operational costs. PWPS designs are not replicas of OEM products, but improved versions based on the use of thermal imaging, stress analysis and component modeling.

Previously improved PWPS 2nd and 3rd stage components are combined with a new 1st stage design to achieve the upgraded 7FA package. This offering provides an 8 MW increase at the 32,000-hour operating interval.

## U.S. LNG export

Tellurian, through its subsidiaries Driftwood LNG and Driftwood Pipeline, has applied to the Federal Energy Regulatory Commission (FERC) to construct and operate a facility for liquefied natural gas (LNG) export in Louisiana, and a 96-mile (154-km) pipeline connecting it to interstate pipelines.

Tellurian expects Driftwood LNG to begin construction in 2018 and produce its first LNG in 2022, with full operations beginning in 2025. Once complete, the terminal will be able to export up to 26 million tons of LNG per year.

## LNG market forecast

An LNG market forecast by Visiongain, a UK-based research firm, predicts that we are entering a period of significant investment in mature and emerging markets. The liquefaction and regasification markets will see high investment in the next couple of years. In addition, growing demand for LNG as a fuel and as a means to supply isolated and small demand centers will contribute to capital spending.

The report found that the small-scale LNG supply chain will continue to expand and that this market will see Capex of $4.35 billion this year. This includes spending on new installations, expansions, upgrades, regasification, liquefaction, LNG bunkering, fueling stations and satellite stations.

## Elliott contract

Elliott Group has been awarded a contract to supply compression equipment for Hengli Petrochemical Refinery's integrated refining and petrochemical complex now under construction in Dalian, China. The refinery, the largest such project approved to date in China, is part of the Chinese government's five-year plan.

The order encompasses 22 compression trains and 28 casings for services including pressure swing absorption, continuous catalyst regeneration (CCR), naphtha hydrotreating, aromatics, coal to $H_2$, propane and isobutane dehydrogenation, and sulfuric acid alkylation.

The units will be built at Elliott's manufacturing facilities in Japan and Jeannette, PA. When it comes online in 2019, the complex will provide high-purity paraxylene as feedstock for Hengli's existing purified terephthalic acid (PTA) plants.

In addition to paraxylene, it will produce gasoline and diesel fuels that meet China's clean fuel specifications, jet fuel, lubrication oils, aromatics, and liquefied petroleum gas (LPG).

Ansaldo Energia's expanded facilities in the United Arab Emirates (UAE)

## MAN digest

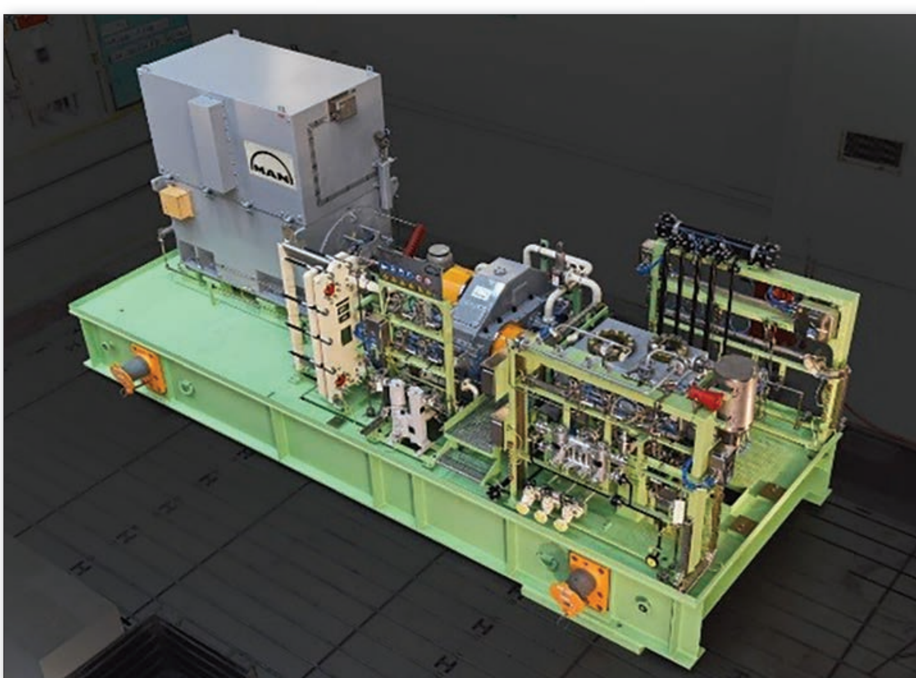
MAN Diesel & Turbo has entered a co-operation agreement with Mitsui Engineering & Shipbuilding that will intensify existing business activities.

The two companies have multiple previous collaborations, and are deepening mutual activities within sales, production, R&D, and engineering, procurement, construction (EPC). They have almost a century of cooperation which is being extended from two- and four-stroke engines to steam turbines and compressors.

Compressor trains from MAN are to be used in gas reinjection and export on new platforms in CNOOC's Dongfang 13-2 gas field, located in China's Beibu Gulf Economic Rim and the Gulf of Tonkin Economic Belt, with an average water depth of 70 meters.

The order comprises three wet gas and three dry gas compressor trains with intercooled barrel type compressors, driven by electric motors with variable frequency converters.

The wet gas compressor trains will be built as standardized and modularized Upstream Packages (U-Pac). This makes it possible to cut lead time and costs. Size and weight are also reduced.



MAN U-Pac upstream compressor package

## Ansaldo contract

Asia Gulf Power Service (AGPS) has awarded Ansaldo Energia a service contract at the Taweelah IB and IBE power plants, located near Abu Dhabi. The contract calls for a permanent maintenance staff on site and covers scheduled overhauls plus preventive and corrective maintenance activities on rotating equipment.

Ansaldo Energia will supply all required spare parts, including GT flow path component repair and refurbishments. Also included are balance of plant (BoP) auxiliaries and condensers.

Taweelah IB consists of six Alstom steam turbines (STs) coupled to six ABB generators, while the Taweelah IBE plant has two GE Frame 9E GTs, one GE STs and three GE generators. The Taweelah Power Plant supplies 2,000 MW of capacity to Abu Dhabi and 160 million imperial gallons per day of water.

Ansaldo Energia has expanded its Ansaldo Thomassen Gulf (ATG) Repair Center of Excellence in Abu Dhabi, as well as a Middle East Service Support Hub in Jebal Ali.

## New APG President

Allied Power Group (APG) has appointed David Theis as President and Chief Operating Officer. He brings over 30 years of operational, business development and leadership experience.

Most notably, he founded and grew Leading Edge Turbine Technologies, which was acquired by Dresser-Rand in 2010. More recently, he served as Senior Vice-President at PAS Technologies leading sales and its energy business.

# INDUSTRYNEWS

*Continued from previous page*

## Wood Group agreement

Hess Corporation has signed a non-exclusive 10-year agreement with Wood Group to provide engineering, project management, construction, commissioning, operations & maintenance, integrity management, subsea, and decommissioning services.

The two companies have worked together for more than 25 years. This consolidates the breadth of their services under one agreement.

## Turboexpander for gas process

L.A. Turbine (LAT) is providing turboexpander units for gas processing and natural gas liquid (NGL) recovery within Honeywell UOP Russell modular gas plant installations. The turboexpander-compressor units are designed to handle a flow range of 60 to 200 MMSCFD for UOP Russell standard gas plants.

LAT manufactures and tests turboexpander equipment in its 90,000 sq. ft. facility in Valencia, CA. UOP Russell plants include pre-engineered modular equipment delivered to remote locations and assembled on-site.

## Setpoint acquired

Brüel & Kjær Vibro (BKV) has completed the acquisition of the Setpoint technology platform from Metrix Instrument. This gives BKV an API 670-compliant machinery protection system, as well as condition monitoring that do not require the level of dedicated computing, software, and network infrastructure typically associated with vibration monitoring software.

This augments BKV's existing portfolio. Setpoint consists of a machinery protection system (MPS) and condition monitoring software (CMS). Its CMS harnesses OSIsoft's PI System.

## GE digest

GE Oil & Gas has signed an agreement to provide two NovaLT12 GTs for cogeneration applications for Italian paper mill, Lucart at two of its Italian locations. The GTs are designed for up to 37% efficiency at full load and allow for standardization and modularization, as well as reduced emissions.

GE will supply the power generation equipment for the Bridge Power plant project in Tema, Ghana. The equipment will be used in the first phase of the project. It will generate 200 MW.

An additional 200 MW will be deployed in stage two of the project. The equipment scope includes GE's TM2500 GTs and STs in a combined cycle configuration. This is the first time the TM2500 will be used in a combined cycle power plant (CCPP).

The 400 MW Bridge Power and LPG import, storage, and transportation infrastructure project will address Ghana's long-term energy requirements by providing enough electricity for 17% of the country's capacity. It can be fueled by LPG, natural gas or diesel. Bridge Power is being developed by the Early Power Limited consortium, which comprises Endeavor Energy, Sage and GE.

GE has received an order from AE Energia for power in Angola. It includes seven TM2500 mobile aeroderivative GTs, services and digital solutions (Predix and Asset Performance Management) for Prodel, the state-owned company responsible for power production. The TM2500s will be installed in Namibe, Huila and Cuando Cubango provinces and will be capable of providing 200 MW.

## PSEG's Sewaren 7

The Sewaren 7 CCPP being developed in Woodbridge, NJ, is part of PSEG's plan to replace units 1, 2, 3 and 4 of its existing coal-fired power plant. Construction commenced in June 2016 and is scheduled to be completed by 2018.

Sewaren 7 will be equipped with GE's 7HA.02 GTs and STs, as well as a heat recovery steam generator (HRSG), a fuel gas heating station, an air-cooled condenser, an emergency diesel generator, an auxiliary electrical building, a main stack, and an auxiliary boiler stack.

The air-cooled condenser will be 125 ft tall and include 20 heat transfer cells covering 40,500 ft². It will continuously recycle water. reducing cooling water needs from a nearby tidal strait. The plant is designed to operate on natural gas and ultra-low sulfur distillate fuel oil.

GE and China's Huaneng Guilin Gas Distributed Energy have announced the first fire of a GE 6F.01 GT. The project is the first-ever gas power project for the city of Guilin and the largest gas power project for the province of Guangxi.

Featuring a combined cooling, heating, and power configuration, the three 6F.01 GTs are said to achieve fuel efficiency of 81.2% and a generating capacity of 210 MW. Under a 1×1 cogeneration configuration, the 6F.01 can reach power generation efficiency of 55.7%.

GE plans to launch a repair and service plant for turbines in Nigeria. The GE plant would be a multi-use facility to support clients in power and oil & gas. Construction work in the southeastern city of Calabar is expected to be

UOP Russell Modular Gas Plant

completed in December.

The company is also part of a joint venture which will begin manufacture of its first GTs in Saudi Arabia by the end of the year. The joint venture with Dussur is situated in the city of Dammam. The first of GE's H-Class turbines will roll out of Dammam by 2018.

GE's Power Services business signed a multiyear service agreement to upgrade equipment at the Ubungo Power Plant in Dar es Salaam, Tanzania, owned by Songas. This encompasses GE's Fleet360 platform for long-term, reliable operation. Upgrades will help Songas increase capacity by 10 MW.

Songas owns six GTs, including four GE LM6000s, which have been operating at Ubungo since 2004. Under the terms of the deal, GE will upgrade three of the four LM6000 GTs in the fleet from the LM6000PA to the LM 6000PC. This is expected to increase the output by 38 MW to 43 MW each. Additionally, they may achieve up to 46 MW with GE's optional Sprint technology. The eight-year deal, which includes maintenance and repairs, will boost plant efficiency by 3%.

## Siemens digest

When completed the Noor complex at Ouarzazate will be the world's largest concentrated solar power (CSP) plant. Noor 1 is up and running with an installed capacity of 160 MW. With half a million mirrors to capture and concentrate the sun's energy, it covers the area of 4,200 football fields.

Mirrors focus the sun's light to heat up a liquid (oil), which when mixed with water, reaches around 400°C. The steam produced is turned into electricity by three Siemens turbo generator sets. Each one comprises a Siemens SST-700, an SST-900 STs and generator. The SST-700 can be used for daily cycling and rapid starts, as demanded by the solar thermal process.

The first Siemens GTs for the expansion of three power plants in Bolivia have been shipped to South America. The two machines, manufactured at Siemens Industrial Turbomachinery in Finspang, Sweden, travel by sea to Chile then overland to Bolivia. Siemens will supply 14 GTs, eleven STs and additional equipment to expand three plants into CCPPs. This will add more than 1 GW.

Siemens has received an order to

The rotor of a Siemens SGT5-4000F GT during assembly

build a cogeneration plant in the Marzahn district of Berlin, Germany. The company will act as general contractor for the energy utility Vattenfall Europe Wärme to erect this natural gas-fired CCPP with district heat extraction. Scheduled to begin operation in 2020, it will produce electric power while supplying the east side of the German capital with district heating. The plant has a capacity of 260 MW and a thermal capacity of 230 MW.

Siemens will work with Uganda and Sudan in the areas of power supply, industry, transportation and healthcare. The African states signed an agreement that includes training programs for local workers.

## World Economic Forum

Uganda and Sudan signed a Memoranda of Understanding (MoU) at the World Economic Forum 2017 in the South African city of Durban. The documents were signed in the presence of Brigitte Zypries, German Federal Minister for Economics and Energy, Joe Kaeser, President and Chief Executive Officer of Siemens AG, and further high-ranking personalities.

Siemens has signed agreements with Pampa Energia to provide long-term service and maintenance at two power plants in Argentina.

One agreement covers the SGT5-2000E GT operating at the Genelba 21 simple cycle plant for 10 years. The other is an eight-year service and maintenance agreement for SGT5-4000F GTs and SST-5000 STs in operation at the Genelba CCPP. The plants can produce 825 MW.

Siemens completed extensive service operations on the GTs at Jebel Ali K-station in 29 working days. The plant, located in Dubai and owned by Dubai Electricity and Water Authority (DEWA), has been in operation since 2002. The outage featured a rotor swap. Upgrades increased power output by 62.6 MW and improved power plant efficiency by about 0.5%.

## Digitization study

A recent research study of more than 200 manufacturing executives conducted by London-based Longitude Research, evaluated digital capabilities to address technologies, such as data and analytics, cloud computing and the Internet of Things (IoT). It revealed two categories for U.S. manufacturers along the path to adopting digitalization: Efficiency experts and revenue re-inventors.

Efficiency experts encourage connected sensors, virtual training and artificial intelligence (AI) to increase uptime and efficiency, and to keep their employees safe. Revenue re-inventors, on the other hand, identify themselves as being financially and digitally ahead of their peers. They find motivation for digitalization in opening up new markets, and reinventing themselves and what they sell.

Study highlights:

• The top five digital technologies implemented by manufacturers include cloud computing at 85%, connected sensors in plants at 65%, connected sensors in products at 59%, 3D printing at 39% and advanced data analytics tools at 34%

• 76% of efficiency experts and 98% of revenue re-inventors stated that they use predictive analytics to forecast performance of production equipment or processes in most or all parts of their organization

• Only one-fifth of the respondents stated that they analyze more than 60% of the production data they collect.

## New ATPS chair

The Asia Turbomachinery & Pump Symposium (ATPS) 2018 is set for March 13-15 at the Suntec Singapore International Convention and Exhibition Centre. This will be the second biennial ATPS, modeled after the longstanding Houston Turbomachinery & Pump Symposia (TPS). ATPS is an international assembly for turbomachinery and pump end-users and manufacturers. It features a technical program selected by an advisory committee of engineers, and an international exhibition. The inaugural 2016 event drew more than 900 atten-

Continued from previous page

Dag O. Calafell, II
Chair

Manoj Gupta
Vice Chair

dees from 38 countries.

The Turbomachinery Laboratory of Texas A& M, host of the ATPS, has named the chair and vice chair for this event. Dag O. Calafell, II, was named chair of ATPS 2018 earlier this week. Calafell has 40 years of experience with end users in oil & gas management, engineering, and operations. He is a member of the Turbomachinery Advisory Committee for TPS. Before retiring earlier this year, Calafell was chief machinery engineer at ExxonMobil Upstream. He has published multiple papers on machinery and flow phenomena and holds several patents. Calafell earned bachelor's and master's degrees from Clarkson University and continued his studies at Columbia University. He will be a keynote panelist at the 2017 ASME Turbo Expo in Charlotte.

Manoj Gupta, a member of the Asia Turbomachinery Advisory Committee, will serve as vice chair for ATPS. Gupta, director of digital solutions at Dresser-Rand (a Siemens business), holds a bachelor's degree in naval and ocean engineering from the Indian Institute of Technology, a master's degree in mechanical engineering from Texas A&M University and a master's degree in finance from the University of Houston. He has published multiple papers in the field of turbomachinery, has a patent and is recognized as a centrifugal compressor expert with expertise in high-pressure compression application.

## MHPS digest

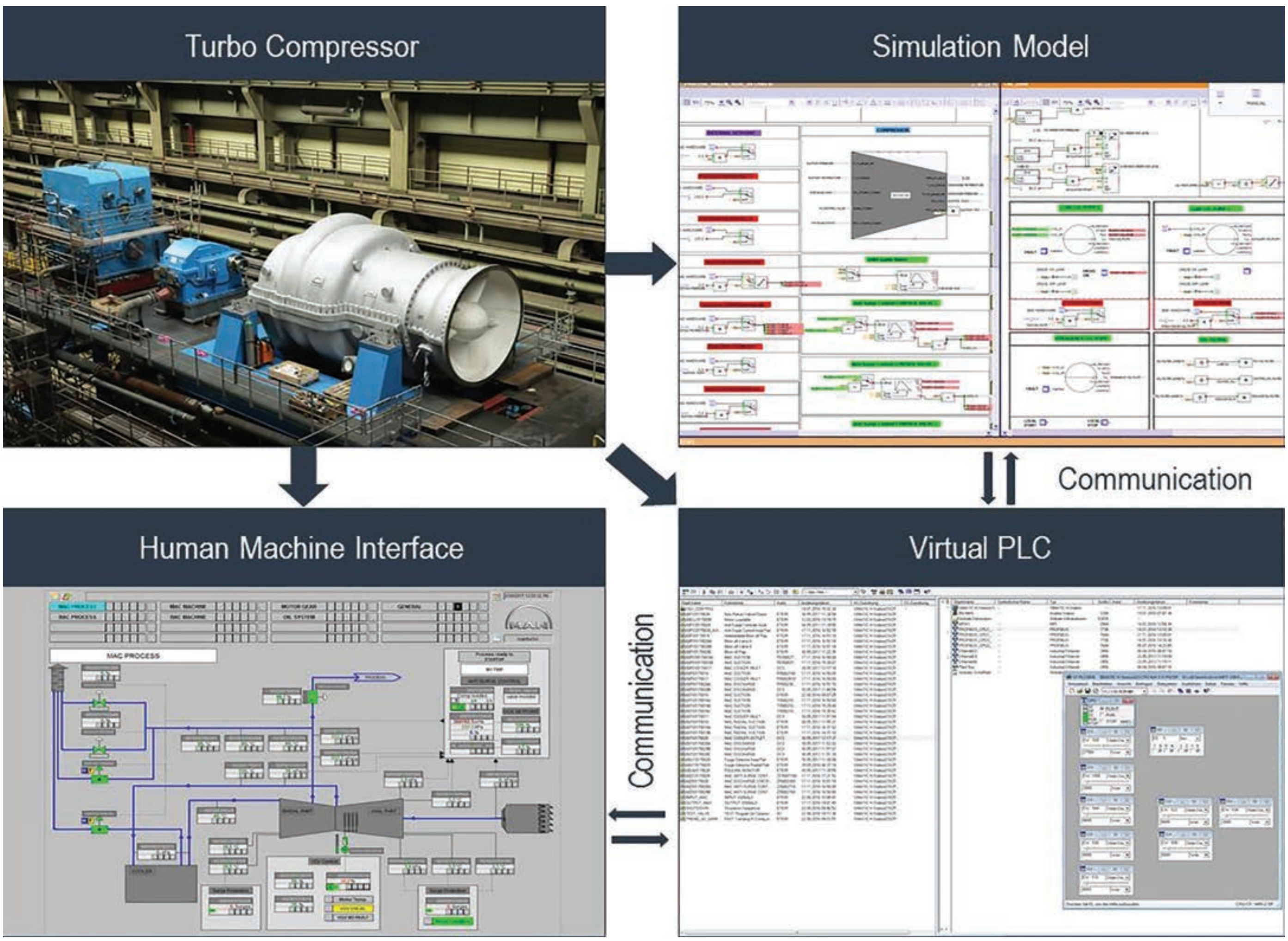
Mitsubishi Hitachi Power Systems (MHPS) reports that it has achieved the number one market share globally among heavy duty (i.e., F-Class and advanced class) GT OEMs in 2017. According to data obtained from McCoy Power Reports, MHPS had first quarter 2017 global orders of 1,544 MW. This equates to a 31.9% share finishing ahead of its competitors. MHPS also was strongest in the Americas, with 1,220 MW in orders (63%). Earlier this year, MHPS recorded 4 million Actual Operating Hours (AOH) of service for its G- and J-Series GTs in power plants worldwide. The MHPS G-Series was first introduced in 1997 and the J-Series was commercialized in 2013. Its installed base of 146 advanced class GTs is said to be larger than the next two competitors combined

Further, Mitsubishi's first J-Series GT installed in the Americas is now operational. The M501J GT is part of a new 495 MW CCPP at the Grand River Energy Center in Oklahoma. The turbine had its first fire on March 14, 2017, and is now selling electricity to the grid. This is the 23rd J-Series GT installed globally. The turbine was synchronized to the grid two days after first fire. The test team demonstrated sustained operations above the Grand River Dam Authority's sellable power milestone. The plant is to be known as Grand River Energy Center Unit 3. It will replace a coal-fired facility. ■

# GET READY FOR THE TURBOMACHINERY CONTROLS REVOLUTION

## TOP TRENDS INCLUDE WIRELESS CONNECTIVITY, DIGITIZATION, RETROFITS, THE CLOUD, DATA VISUALIZATION, ANALYTICS, IT INVOLVEMENT, CYBERSECURITY, DECENTRALIZATION AND THE MOVE TO OPEN SYSTEMS

**BY DREW ROBB**




Courtesy of Man Diesel & Turbo

MAN Turbo & Diesel controls monitoring an axial compressor

Not so long ago, the turbomachinery controls marketplace was relatively stagnant. What a difference half a decade makes. Several trends are shaking the very foundation of the industry. They include greater use of wireless connectivity, digitization, retrofits, the cloud, data visualization, analytics, far more IT involvement, the vital necessity of employing cybersecurity safeguards, decentralization and the move to open systems.

Wave after wave of IT technology and innovation are finding their way into plant control software. This is gradually bringing an end to a long-held separation between plant, turbomachinery and IT systems. As these worlds collide, problems are inevitable — cybersecurity is one symptom of the initial teething troubles.

The adventurous will boldly adopt the latest and greatest and bet the business on it. The cautious will wait in the sidelines to see how it all plays out. As to which strategy is correct, only time will tell. But if the retail sector is any sort of guideline, those late to the digital party may struggle to remain competitive.

Companies, such as Rockwell Automation, Emerson Automation, Woodward, Tri-Sen, Elliott, EthosEnergy, MAN Diesel & Turbo, GE Oil and Gas, Siemens, MHPS, Petrotech, Solar Turbines, Energy Control Technologies and Schneider Electric are in the forefront of this revolution. Here is how they are adjusting to these trends and how they are gearing up for the future.

## Rockwell Automation

Rockwell Automation recently expanded ITS ControlLogix portfolio with the ControlLogix 5580 controller. It is said to enable faster system performance, reduce system complexity and support enhanced security in an effort to help customers to future-proof their systems.

Rockwell Automation also offers Dynamix 1444, which provides condition monitoring and machine protection in an integrated, configurable module. The goal is to prevent downtime and damage to critical machinery by providing real-time access to equipment health data.

Finding ways to remove the risk of obsolescence and to break upgrades down into smaller projects has been a successful strategy for many customers. If you can identify opportunities to make an impact, it will make the longer-term journey more achievable.


The Allen-Bradley 5580 ControlLogix by Rockwell Automation

"Turbomachinery OEMs are gaining more of the package, including balance of plant (BOP) control for a greater level of turnkey responsibility," said Julie Robinson, Marketing Manager, ControlLogix controllers at Rockwell Automation. "End users want to have modularity and portability, but they want users to have the same experience when interacting with different control systems."

As a result, Rockwell Automation has seen a surge in its turbomachinery retrofit business, particularly in vibration monitoring and remote monitoring, as a means of avoiding obsolescence and minimizing unplanned downtime.

"Digitization impacts every aspect of operations and supply chains," said Robinson. "Becoming a digital business is a journey and businesses must first achieve an end-to-end integration of their data."

This requires the integration of industrial software and automation, the expansion of communications networks and security, and the use of business-specific industrial services.

IT company Cisco predicts there will be an estimated 50 billion devices on the internet by 2020. The potential benefits to digitization include reduction in energy consumption and downtime, improved quality, elimination of human error, improved planning and forecasting.

Rockwell emphasizes the cloud and wireless technology as crucial elements of the transition.

"Wireless will be pervasive, taking many forms such as WiFi, cellular and Bluetooth," said Robinson. "We're also seeing a lot of value in location-based services so that operators can access the information they need based on what machine they are standing in front of."

Rockwell's ThinManager product with Relevance, for example, provides the ability to deliver applications to people when and where they need them.

The company cited research showing that 7% of scheduled runtime is affected by unplanned downtime. Major contributors include user error, aging equipment, and lack of information. Additionally, many organizations do not log or know the cause of a downtime event. The problem is not lack of data, it is lack of connectivity, added Robinson.

"Being able to take data from a device, summarize and aggregate it to be able to make real-time decisions takes away ambiguity for users," she said. "Modernizing their equipment helps them gain insight into their data. They can begin to use it proactively, to help predict when maintenance may be required and ultimately minimize unplanned downtime."

## EthosEnergy

EthosEnergy reports that a plant's IT support team is increasingly becoming a member of the decision team for control system retrofits. This has changed the way control products and features are marketed as this important group now needs to be satisfied.

"We have to be conversant in industrial networking, including topology, security and software patch updates," said Jeff Schleis, EthosEnergy Product Marketing Manager, Optimization & Upgrades. "From sales through aftermarket services, we continue to be challenged to be knowledgeable and to stay up to date."

He said file sharing in the cloud has improved communication with customers during the design phase. It is rare, these days, that design reviews are performed in person. Instead, EthosEnergy relies on technology to improve collaboration. Cloud-based services are also proving useful in remote monitoring and diagnostics.

"We are using the cloud to store data and provide the front-end in a familiar format," said Schleis. "By leveraging data visualization software we are extending data from the cloud to tablets and phones to make it easier for users to get the instant feedback everyone is accustomed to."

This opens the door to real-time alerts of plant issues via automated emails. The user can then immediately check the details on their phones by accessing a controls interface over the web.

But EthosEnergy is cautious concerning the deployment of wireless technology. Schleis believes the turbomachinery controls sector is correct to be slow to adopt wireless. Particularly with concerns around cybersecurity, wireless tools and security technology requires further maturity before seeing broad adoption in power plants.

Greater involvement by the IT department means old-guard controls specialists will have to learn and grow accustomed to new skills. The IT department of a utility or independent power producer (IPP) will be included on more retrofit projects. Thus being able to package an operator terminal or engineering workstation as a virtual machine (VM), a technique long used by IT, is gradually finding its way into the controls repertoire.

"When the virtual machine is located on a central server, thin clients provide easy maintenance and replacement, low cost hardware and high reliability," said Schleis. "Backup and restoration are made easier with a VM and it is in a format that

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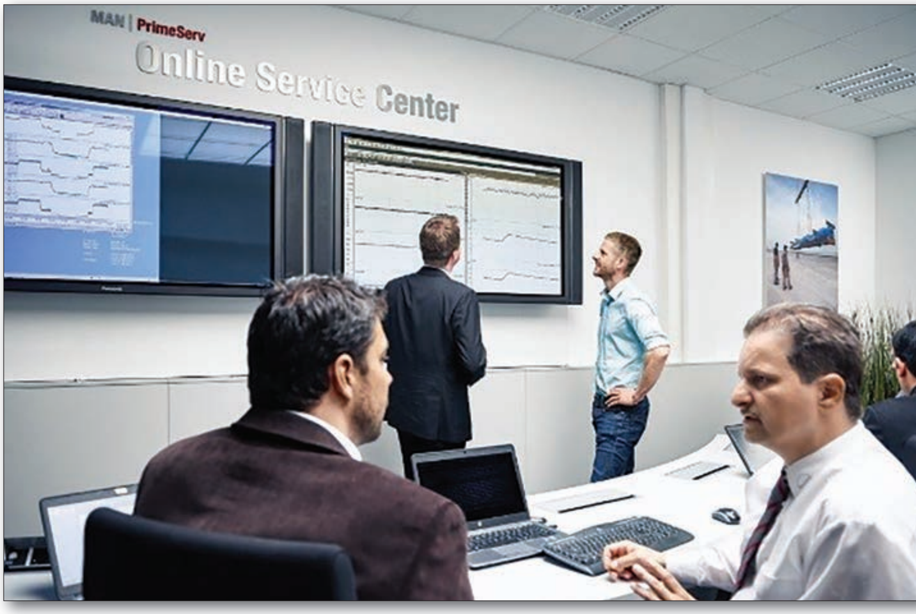


The MAN PrimeServ Online Service Center monitors turbomachinery around the world

the IT department is familiar with. Adding this proven technology to an upgrade is gaining more user support."

The drivers for controls upgrades are also shifting. External sources and regional governing entities such as the North American Electric Reliability Corporation (NERC) are compelling power plants to guard against cyber threats or face fines. Another example of external influence might be the need to shorten the start time of the unit, allowing the asset to be more competitive in the power market and increase revenue.

Schleis advises users to identify the source that is driving the upgrade and communicate that to vendors. By helping vendors understand and appreciate driving factors, the user can obtain more workable solutions to the problem.

Such demands from outside forces can also be a factor in the decision to upgrade an aging controls system. Veterans at the plant may point out that the existing system has been performing well.

In many cases, they are correct to argue against an upgrade to the latest and greatest for its own sake. The point that is sometimes missed, however, is that there may be reasons for an upgrade that go far beyond avoiding obsolescence and future unavailability of parts or support.

"If the control system is not causing problems, then obsolescence will never be a financial driver for change," said Schleis. "Only with added value in other areas does a control system replacement make financial sense."

This value might come in the form of decreased costs from increased automation, commonality of hardware with plant systems, and more uptime. It requires in-depth engagement with trusted vendors to discuss ongoing needs and how new controls may help.

## MAN Diesel & Turbo

Innovative and optimized control solutions have become a pillar of product development at MAN Diesel & Turbo. This includes more flexible programmable logic controllers (PLC), as well as ongoing projects related to cloud technologies, and intelligent controllers like the Model-Based Predictive Controller, a new Steam Turbine Multifunctional Controller and an Anti-Surge Controller for axial and centrifugal compressors.

Additionally, Software-in-the-Loop (SiL) and Hardware-in-the-Loop (HiL) simulation-based pre-commissioning has become an integral part of MAN's software development process. This has helped the company improve software quality and reduce commissioning time.

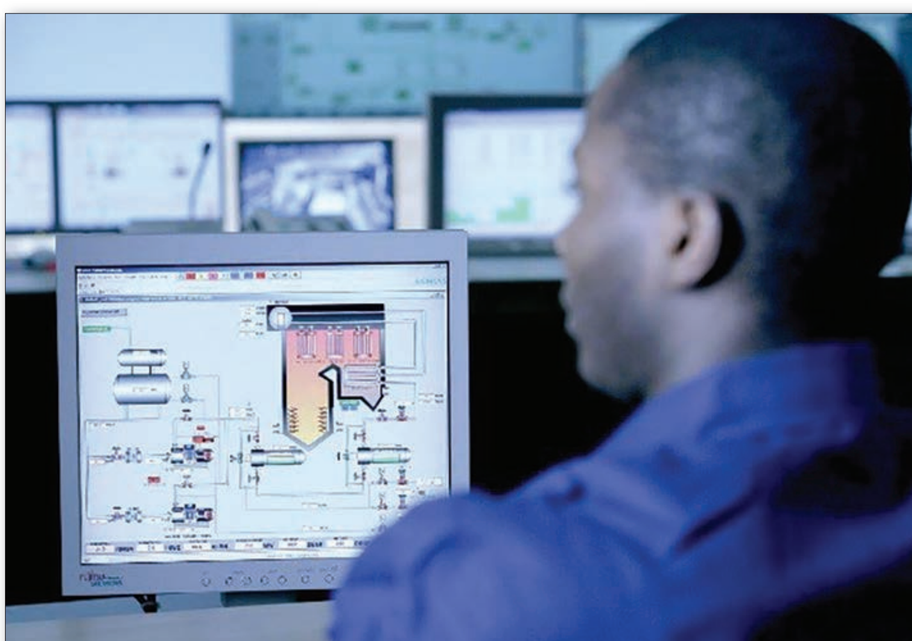
"Only the use of modern intelligent control solutions makes it possible to fully exploit technology's potential down to every decimal place," said Dr. Alexander Sobolyev, Head of Instruments & Controls Research & Development, MAN Diesel & Turbo. "Older control systems are often not able to provide the required performance. But train availability and process stability can be enhanced by updates or retrofits."

Greater prevalence of cyber-attacks on industrial control systems in recent years has seen cybersecurity gaining more importance. And the combination of simulation techniques with sensor data has assisted MAN in the creation of digital twins for turbomachinery assets. This allows the company to predict and optimize how machines operate.

## Siemens

The latest innovations to the Siemens SPPA-T3000 power plant control system are based on industry research. This uncovered the importance of the interface between people and machines in plant availability and reliability.

Thus, Siemens has developed an operator-centric approach via a new Human Machine Interface (HMI). This covers prioritization of plant situations, being able to configure the workbench to user needs, and giving consideration to ergonomics to make it easy for system interaction.


The operator workbench for Siemens' SPPA-T3000 power plant control system.

This includes intelligent alarm handling, which provides guidance to the operator in critical situations and workflow support for the daily routine. Siemens also supports data applications running outside of the control system. This encompasses cloud apps, such as the Siemens Data and Security Gateway released last year.

Dieter Fluck, Vice President of the Controls Technology Portfolio in the Power Services Division at Siemens, commented that the company has stepped up its efforts to ensure that plants and turbines are equipped with the latest security technologies. For example, Siemens has enlarged its IT security portfolio with application whitelisting which prevents the execution of unknown software and potential malware in the SPPA-T3000.

When it comes to controls upgrades, Fluck recommended that plants combine maintenance and turbomachinery upgrading with controls upgrades. Even though the control system upgrade is potentially a much smaller project compared to turbine maintenance, he said it can significantly contribute to an increase in availability, efficiency and start-up-reliability.

"Consider reworking vintage turbine controls system with the aim to minimize mechanical and hydraulic components and move into electronic controls," said Fluck. "Keeping current with the most recent upgrades, updates and patches is a mandatory security requirement."

For those remaining on aging systems, Siemens supplies spare parts for systems older than two decades. It recently launched the extension of its service program for users operating the former TXP platform. But in most cases, control system operators have been moving to the most recent version of SPPA-T3000.

## Standardization

To increase productivity in power generation, the company is investing heavily in digitalization. This implies the need for standardized communication and connectivity, and the ability to integrate with third-party systems based on common standards. Additionally, the company has noticed a steady shift from large, centralized generation towards smaller, decentralized generation.

"Turbomachinery control systems need to fit smaller generation units without losing the capability to handle increasing complexity," said Fluck. "But they also need to be easily integrated into a whole energy system and managed as a fleet remotely."

Siemens systems incorporate wireless technology. But the company is not seeing significant demand for wireless-enabled turbomachinery controls.

Siemens added more digitalization to the latest release of its control system. For example, a software tool collects data from the controls system archive, as well as engineering data and data from edge devices, which is sent securely to the cloud. Cloud-based data analytic apps can then drive engineering optimization and operations performance enhancement of turbines and power plants.

## Elliott

The most critical need of Elliott customers is to run without interruption between scheduled shutdowns. Recent improvements to its controls address system availability via testable trip manifolds, partial stoke testing of turbine and expander trip valves, and improved system redundancies.

"We must provide our customers with systems that are easily operated, maintained and understood," said James Dugan, Controls Lead Engineer, Elliott. Toward this goal, Elliott has developed more understandable HMIs and incorporated the implementation of PLC systems familiar to specific users, or project-specified, plant-wide distributed control system (DCS) hardware.

The first Elliott PLC-based systems were installed in the mid-90s to the early 2000s. Some of these systems are approaching hardware obsolescence. The company informs users of the issues and offers possible solutions, such as newer replacement parts, or an upgrade path to a new hardware platform.

Full system replacements, though, must be planned well in advance of shutdowns so that the application can be built and tested, and cabinet modifications can be well thought out. If the project is well planned, modifications can generally leave most of the existing wiring undisturbed, and system functionality can be thoroughly tested well before actual implementation.

"It is not a trivial task to remove an existing system, install the replacement, perform loop checks and acceptance testing, and commissioning, all within a period of a few weeks to meet the scheduled restart of production," said Dugan. "But the cost of just one unplanned shutdown could pay for the upgrade."

With the widespread adoption of IEC61511/ISA84 (a technical standard which sets out practices in the engineering of systems that ensure the safety of an industrial process through the use of instrumentation), he added, there is a focus on compliance. Under the SIS Safety Requirements Specification (SRS), these standards list the maximum allowable spurious trip rate for the functions of the safety system.

However, any issue that will not allow you to run properly, such as a nuisance upset has the same impact as not being able to run at all. Even little things, such as the lack of field device redundancy, can jeopardize the productivity of critical plant processes all for the sake of an additional transmitter.

Historically, control system speed was the limiting factor in turbomachinery control implementation. This is becoming almost a non-issue, said Dugan, as the ever-increasing performance of computer hardware either enables more functionality or opens up other control system platforms for use. IEC61131 compliance allows for easy migration of proven logic into these platforms.

Redundant Tri-Sen TSx system for a steam turbine-driven Elliott recycle compressor at a plant in Egypt

"We have seen control systems (including compressor anti-surge, combustion and steam turbine control) implemented within various DCS platforms (800xA, C300, DeltaV) long considered too slow for this sort of application," said Dugan. "Our customers are also requesting security features, such as hardware-based industrial protocol firewalls, and the implementation of least privilege security strategies."

Elliott sees a role for wireless solutions where connectivity is a problem. As such, wireless is more likely to be used in a system modification rather than a new installation. That said, wireless may not be ideal where runtime is to be maximized and the spurious trip rate is to be kept at a minimum, noted Dugan.

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Petrotech offers turbomachinery and process control systems for gas and steam turbines, generators, reciprocating and centrifugal compressors, pumps and ancillary systems.

## Petrotech

Unless a customer specifically requests a proprietary system, Petrotech offers them an open architecture control system. Proprietary systems can be more difficult to maintain due to obsolescence and communications limitations, said John Kazour, President of Petrotech, and integration into companywide IT systems is more cumbersome.

"This is becoming more important with the explosion of big data integration and predictive analytics," he said. "Systems should be designed with standard languages and interfaces to minimize errors in data integrity and sharing with plant networks."

The Petrotech approach is to enhance data accessibility to other systems without compromising the ability to protect the machine. Users are given access to needed data but the protection system is isolated from the network to increase availability and minimize the potential for user errors.

Machine availability should determine when to perform upgrades, said Kazour, as this provides the easiest cost justification. Machines in standby or peaking mode, where 100% availability is not critical, will require minor upgrades.

Such upgrades will avoid the situation of components no longer being manufactured, and increase the amount of actionable information.

"New systems provide the data needed to make intelligent decisions at the machine and plant levels, providing users more opportunities to reduce maintenance costs," said Kazour. "Users should decide when to upgrade based on the significance of machine availability to operations."

## Emerson

Emerson has incorporated new technologies into its Ovation control system, extending the automation platform beyond the bounds of traditional distributed plant control.

It recently introduced:

• Ovation Machinery Health Monitor, an integrated solution for simplifying and improving protection and prediction of rotating assets

• Integrated Ovation Excitation Solutions for generator control

• Ovation Embedded Simulation technology, offering high-fidelity models embedded into virtual controllers.

New products are being developed with a reduced footprint that can be applied to smaller turbine applications.

"Users now have a common set of engineering tools to manage models and control logic, making it easier to keep the simulator up-to-date," said Brett Benson, Director of Gas Turbine Solutions at Emerson Automation Solutions. "Embedding these capabilities on a common platform offers reduced costs, less complexity and improved reliability.

Combined cycle operators, he said, are focusing more on automation in light of the changing generation landscape, driven by how the rise of renewables and low gas prices have changed the way turbines operate.

Coal-fired plants that had historically provided baseload power are now cycling; gas-fired units that had been used for cycling are now providing baseload power; and even some simple-cycle plants that were peakers are now operating almost daily as cycling units.

These operating changes put additional stress on turbomachinery. That stress can be cut down by automation. It can also be used to improve the response of steam turbines to load swings, as well as lower maintenance costs by converting mechanical-hydraulic controls to electro-hydraulic controls.

"The need for high availability and reliability is more critical than ever, particularly for power generators where inability to meet startup requirements can mean lost revenue," said Benson. "A control system can improve availability of a simple-cycle fleet by executing daily unit start-check algorithms. It can monitor combustion dynamics and exhaust profiles to detect combustion hardware anomalies.

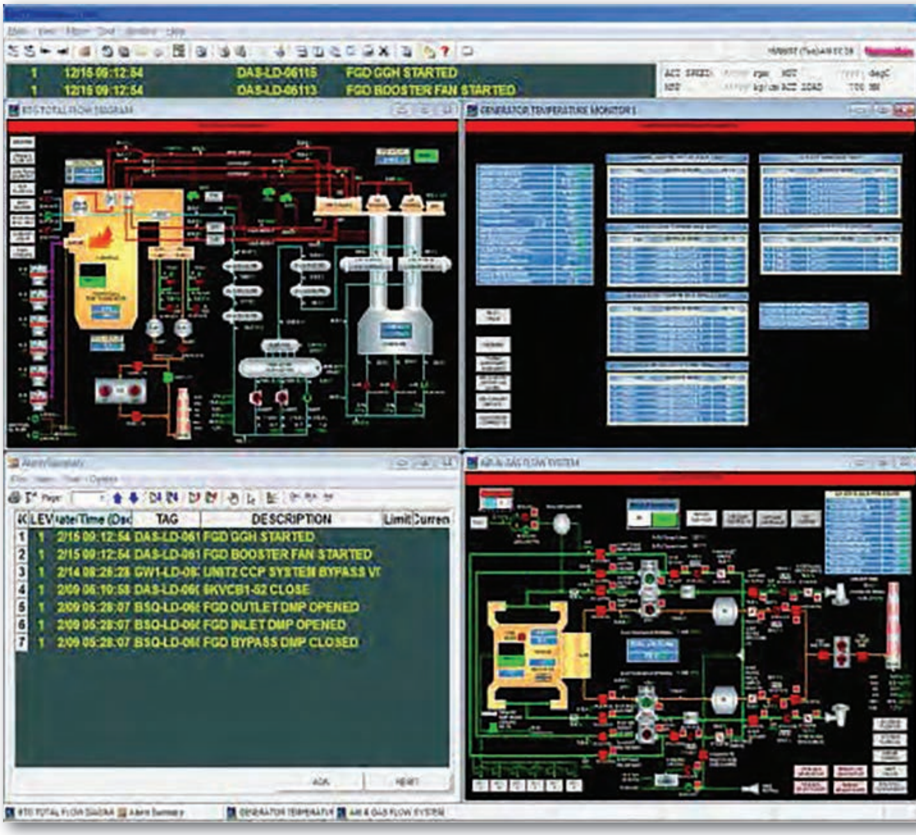
Lack of availability of board-level components like PCI cards used in aging hardware is only one reason to upgrade an old system, he said. It may also be difficult to locate personnel with the knowledge to replace them.

Critical infrastructure protection (CIP) requirements specified by NERC can induce power generators to upgrade their control systems. This set of requirements is designed to secure the assets required for operating North America's bulk electric system.

Another challenge is write-cycles (the number of times you can write data onto a device) reaching maximum. Some legacy control system boards reach a maximum number of writes, then can do no more. This may prevent set points from being entered or new constants being used.

Emerson Automation offers cloud-based services, such as PlantWeb Insight and PlantWeb Advisor for those who are ready to adopt this technology. But in the company's experience, power generators are in no rush. However, wireless technologies continue to expand beyond the basic temperature, pressure and flow variables.

"Emerson continues to develop wireless devices for new applications, includ-



MHPS controls screen

ing non-intrusive corrosion detection, acoustic monitoring, gas monitoring, power metering and passive medium voltage temperature monitoring," said Benson. "This enables plants to pull in data from remote areas or where it is impractical to hardwire devices, due to cost or location. We're seeing some utilities starting to use wireless routers to collect data from pockets of wired instruments. They can then bring it into plant information systems to apply pattern recognition technology or thermal models to detect anomalies."

## MHPS

Mitsubishi Hitachi Power Systems (MHPS) is involved in maintenance of current DCS as well as the next generation of DCS, based on demand for stronger protection and functionality.

The latest enhancements are focused on implementing virtual DCS and cyber security measures built on the MHPS-Tomoni platform. The company's security standard exceeds the currently mandated NERC-CIP requirements for industrial power generation sites.

"We provide at least 15 years of hardware parts support while also providing transition models," said Scott Cloyd, general manager of Gas Turbine Service and Design Engineering, MHPS. "Our approach addresses vulnerabilities to cyber-security attacks from obsolete equipment and software, and enables operators to take advantage of technological improvements to manage assets."

## Woodward

Woodward's latest enhancement is point-of-use configurable controls (Peak200, 505, Flex500 and Vertex) for steam, gas, hydro and compressor applications. They permit users to access a color display to control a turbine's performance, efficiency and productivity, as well as adding a troubleshooting capability.

In addition, OptiTune PID technology allows the controller to optimize turbine performance. The company has developed integrated capabilities to monitor bearing temperature, rotor vibration, lube oil pressures and other turbine parameters with visibility on an integrated HMI screen. Its centralized control platforms have high-performance microchips to manage diagnostics, and cybersecurity upgrades.

"Controls require little to no maintenance compared to mechanical valves, actuators and governors," said Eric Friehauf, Woodward's Aftermarket Manager. "But we recommend that spare controls that have been on the shelf for multiple years without operation be added to site maintenance checklists for power up, software upgrades and certification, so they are ready when needed."

Company policy requires its latest controls to be backward-compatible and to offer an efficient upgrade path when support for spares and repair are exhausted. This includes servicing products from decades ago. When possible, new products or modules are designed so they can be drop-in replacements like its 505 steam control.

Friehauf has observed a trend of heavy duty frame GTs toward electric actuation, valves and drivers which require additional control capabilities. The catalyst for this trend is increased performance, reliability, and data capture, management and analysis. This supports the improved diagnostic and prognostic needs of operators.

Another growing trend is distributed Input/Output (I/O) technology. This is said to reduce the total installed cost to the user and simplify system architecture in terms of reduced support. Distributed I/O helps to improve control point accuracy, contributing to faster, more reliable starts, lower emissions and lower operating costs, added Friehauf.

"There is increasing demand for a secure solution for remote access, monitoring, diagnosis and system control adjustments to optimize performance and manage with fewer trained resources on-site," he said.

## GE Oil & Gas

GE Oil & Gas is heavily investing in digital technology to simplify rotating equipment, reduce maintenance activities and boost asset performance. New control algorithms leverage digital twins.

These are physics-based models tied


Woodward 505 steam turbine controls

into analytics that are used to estimate and predict the future state of a turbomachinery asset. An outgrowth of this is the "synthetic sensor." The idea is to leverage the digital twin to estimate process value and avoid the use of real sensors that in case of failure may negatively impact the

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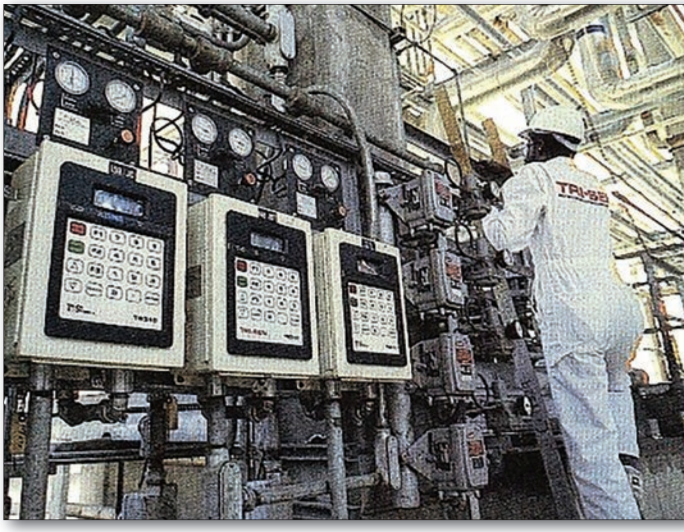

Tri-Sen 310 rack

An operator at a Solar Turbines control panel

equipment performance.

Quick migration kits are available to upgrade an obsolete control panel to the latest platform. Compared to a normal upgrade, it requires only 30% of the time.

"As the control system represents the mind of an asset, it is wise to keep it healthy and updated," said Carlo Snickars, Product Leader, Controls and Cyber, Turbomachinery & Process Solutions, GE Oil & Gas. "Upgraded control systems also enable enhanced cybersecurity."

GE's Predix platform for the Industrial Internet has been designed to connect equipment, analyze data, and deliver insight in real time. Predix cloud-based apps, such as Asset Performance Management, are said to make operations safer and more reliable while helping to ensure optimal performance at a sustainable cost.

Wireless technology is part of the shift towards digitized, IT-centric controls. It cuts down on installation time, avoids cable routing and loop check at the site. Snickars pointed out that this technology is widely used for monitoring purposes, but is gradually being broadly adopted for equipment control.

"Battery life seems to be the main technological challenge, but we are confident that this gap will be solved soon," he said.

## Tri-Sen

Tri-Sen has improved connectivity along with security on its standard product line. Improvements include Bluetooth, wireless, the adoption of industry standards for device integration, as well as obtaining cybersecurity certification (IEC62443) for its PLC. Some older products have received component upgrades to improve connectivity and support the installed base into the foreseeable future.

"The maintenance advice we give to our customers is simple: Register products, and update maintenance and engineering contact information so you receive any application and product notes relating to controls products," said Tom Bailey, Director of Marketing, Tri-Sen.

Market maturity has reduced the difference in fundamental features and performance between the leading controls platforms, said Bailey. Until a new technology disrupts the market, any real differentiation among turbomachinery controls providers will most likely occur in three places:

- Design of the new system with respect to process integration
- Method of delivery
- After-sales service and support.

Integration and use of high-fidelity process simulation is one example of differentiation in the design of replacement controls.

Simulation should be used by controls providers: Both in the design phase of a project, to ensure that the existing process is considered; and during validation testing to make sure the controls system will function correctly when it arrives on-site.

Tri-Sen has seen an increase in requests from users to integrate some, if not all, of their turbomachinery controls onto their DCS. "While there is an important market for stand-alone turbomachinery controls, the improvements in DCS processing power and performance means that the DCS integration approach may make sense for certain applications."

## Solar Turbines

Building on its Turbotronic platform, the Turbotronic 5 from Solar Turbines introduces four major enhancements. Controller Access Security includes a central software security application manager that enables users to assign multiple levels of access. These range from "view only" to full software programming based on job function. This guards against unauthorized access and cyber threats.

The Rockwell Dynamix 1444 vibration monitoring system, in conjunction with Solar's TT4000 HMI version 5, provides condition monitoring features. It includes display of waveforms, such as frequency spectrum, phase angle, orbitals, waterfall plots, and trending to aid with machinery health diagnostics and troubleshooting.

It can be paired with Solar's InSight platform for advanced monitoring and analytics. Additionally, HART-enabled analog input modules have been added for transmitter configuration and faster fault identification; and the Ethernet/IP device-level ring increases data bandwidth and enables quick identification of communication faults.

Solar's aim is to provide 10 years of support after a control system is discontinued. Historically, the company has been able to exceed this timeframe for most systems. It also offers customers the opportunity to upgrade stand-alone systems, such as fire monitoring, vibration monitoring and HMI fuel system modules. Each can be upgraded independently without changing the entire control system.

"The most important trends are the introduction of data analytics to improve the user's ability to reduce unplanned downtime by performing condition analysis; and implementation of security measures to prevent unauthorized intrusion," said Alex Troya, Global Manager for Customer Service, Project Applications Engineering, Solar Turbines. "Turbotronic 5 addresses both trends."

Solar has embraced digitization through the development of the InSight platform, which serves as the technology foundation for service delivery. It is enabled by a secure connectivity architecture. It ensures remote read-only access to machine data, from the turbomachinery controller to the data acquisition device, to the end users' PC or mobile device. It makes a wide range of machine performance and fleet data is available to users.

Foxboro EVO controls by Schneider Electric

## Schneider Electric

Schneider Electric's Foxboro Evo uses high-capacity, high-availability control processors and I/O, as well as role-based engineering tools. A recent enhancement is the amount of data that can be transmitted from the controllers and plant assets into the historians and the cloud.

"Turbomachinery controllers have always been connected to provide information on the condition of the unit, alarms in the process and data dumps for historical purposes. But only a limited amount of data was being transferred," said Tim Pieszchala, Global Systems Architect, Schneider Electric. "But with today's technology, rotating assets can provide far more data to the people responsible for improving the safety, reliability, efficiency and even profitability of the operation."

For example, the company's PRiSM can be combined with its cloud-based Maintenance Response Center for condition monitoring and asset management. This delivers asset-performance and asset-reliability data. Pieszchala stated that the maturity level of modern technology is realizing the potential of predictive maintenance and condition monitoring.

"Turbomachinery controls are typically about five years behind others in the automation industry. They need to be proven in the field before they can be applied to rotating equipment," he said. "A new wave of Industrial Internet-enabled systems already being implemented in some process plants will eventually be considered for use in the next round of control upgrades."

The Open Process Automation Forum (www.opengroup.com) is exploring more open platforms that allow systems and assets to be enhanced without replacing anything, and without relying on a single-source provider, he said.

This allows users to be selective and strategic about how and when they will upgrade. It could facilitate better performance control of operations at the asset level — from a piece of equipment all the way across their enterprise asset sets, and even into their supply chain.

"Future automation system architectures will provide asset performance control from the bottom up, from equipment assets to unit, area, plant and enterprise assets," said Pieszchala.

## Energy Control Technologies

Energy Control Technologies (ECT) provides turbomachinery control systems on open platforms. Paul Fisher, the company's President, said this eliminates the costs associated with developing and maintaining proprietary hardware, operating system software, and HMI software. He recommends users move away from proprietary hardware platforms because of regular upgrade requirements.

"We focus on application software and algorithms that provide customers with value leading to production increases, energy efficiency, and improved machine protection," said Fisher. "Open platforms allow spare parts to be sourced locally by the end user at a fraction of the cost."

He has seen turbomachinery control systems manually operated in the field after initial commissioning mainly because the systems are not capable of handling larger process disturbances. Additionally, users do not remember how to maintain proprietary system so switch them to manual. This defeats the purpose: Controls running automatically.

ECT's focus is on remote connectivity to systems to provide lower cost support, troubleshooting and data archiving. Fisher has not seen wireless transmitters on critical turbomachinery applications. ■

Emerson Automation Ovation controls monitor turbomachinery and plant assets

OPERATIONS & MAINTENANCE

# ENHANCING GAS TURBINE PERFORMANCE

## GAS TURBINE OPERATION CAN BE OPTIMIZED VIA DATA COLLECTION, ANALYSIS AND PRECISION FLOW TESTING

**BY RICHARD VOGEL**

Precision flow testing can play an important role in optimizing gas turbine performance. It can determine the performance and expected lifespan of individual components vital to maintaining a reliable and profitable gas turbine.

By combining this information with performance and emissions data, it is possible to suggest improvements to individual components that will benefit overall turbine operation.

Due to the complex nature of individual components and the need for strict tolerances, a small anomaly can develop into a more serious issue that can affect the service life of combustion and hot-gas-path parts. This can result in increased repairs to components, de-rating of the machine, or even taking the gas turbine offline.

Data for each component's flow test is collected, recorded and reviewed. It is then used to assess the component's condition and useful life.

Figure 1: Inspection of 501 FD2 dual fuel support housing in Sulzer's 450 kV, 5-axis digital imaging X-ray booth

### Optimizing combustion flows

Vacuum flow testing replicates the direction of flow that occurs on combustion components while in operation. It helps to verify and adjust the flow rate through combustion liners to ensure temperature uniformity (Figure 1).

Fuel enters and mixes with air in the primary mixing zone of the combustion liner. Supplied air is directed through mixing, dilution and the louver features of the liners. The position, size and effective flow area of these features affect the fuel-to-air ratio, flame temperature, flame profile, and ultimately the performance and emissions of the turbine.

The effective flow area of combustion liners may change following a repair. This may result from the removal of thermal barrier coatings and base material, for example. Therefore, the effective flow area needs to be carefully tested after new barrier coatings are reapplied.

Flow testing of first-stage nozzle vane segments should also be considered (Figure 2). The first-stage nozzle consumes a significant portion of air supplied to the compressor discharge case. Turbines that underperform can be affected by the oversupply of cooling air to the first-stage nozzle vane segments. This simultaneously reduces the required air flow for combustion within the liners, limiting the output performance of a turbine.


Figure 2: Flow test of 501 DF42 fuel nozzles with steam injection on high-flow test bench

Gas turbines operate in environments where small particles can be ingested and deposited on components. The fouling or blockage of fuel nozzles, for example, can significantly affect turbine performance.

It can also lead to physical damage of the machine. Therefore, blades and buckets should be tested to check that cooling passages are not blocked (Figure 3). Evaluating uniformity in sets of component flow data can help pinpoint parts that have issues.

By comparing data from tests performed when parts are received to those performed after refurbishment, it is possible to identify problems. Trending this in-

Figure 3: Flow test of 7001 1st stage bucket on high-flow test bench

formation over time can help develop more informed maintenance schedules and estimates of useful component life.

Liquid flow testing monitors the flow rate of liquid-fuel and water-injection circuits of the fuel nozzles. Liquid flow testing also allows for the visual monitoring of spray patterns, which can indicate component wear or internal blockages.

Liquid circuits need to maintain their spray patterns in order to achieve the correct flame profile and temperature distribution. Wear or internal debris may cause combustor burnout. If this occurs, the flame can impinge upon the combustion liner or basket wall and cause component damage.

## Assessing liquid flows

Fuel nozzle flow rates need to match those required by the manufacturer's design specifications in order to achieve the expected output. These criteria may vary from one turbine to another, even if the turbines are of the same model type. An evaluation of flow data should be performed and made available for inventory spares or sets of fuel nozzles.

Large operators minimize downtime during outages by using inventory spares. Spare fuel nozzles, for example, should be clearly identified with a reference that identifies the turbine they originated from and specific flow data.

Large organizations that operate multiple turbines in different locations with an inventory pool of spare parts, may have performance issues after swapping out for an inventory set.

For example, fuel nozzles designed for a turbine at sea level will have different specifications than the same model at another elevation. Without a comparison of flow rates, unknowingly swapping these fuel nozzles can reduce performance and may even affect start-up.

It is wise, then, to carefully review flow data from parts being removed from the turbine as well as those scheduled for installation to ensure there are no major differences.

Even when minimal differences are present, this analysis can determine the need for other actions, including changes to fuel valve settings, operational control adjustments or scheduling the turbine for tuning.

Ultimately, flow testing aims to remove anomalies from a system, minimizing variation and delivering a more efficient machine. Minimizing temperature spread and vibration reduces wear to components, lowering repair and maintenance costs. ■

*Richard Vogel is Fuel Nozzle & Flow Test Engineer at Sulzer. For more information, visit www.sulzer.com*

# COMBUSTION TURBINE EXHAUST DUCTS

## PROBLEM AREAS FOR TURBOMACINERY EXHAUST DUCTS MUST BE UNDERSTOOD AND SOLVED TO ACHIEVE OPTIMAL PERFORMANCE

BY SCOTT OLSON & KEVIN MORALES

Power plant gas turbine (GT) exhaust ducts are exposed to challenging conditions that require diligent inspection and maintenance to keep the ducts reliable. The consequences of not maintaining this duct section include: Expansion joint failures from fabric overheat; internal liner plate and insulation liberation, which results in fouling of Heat Recovery Steam Generator (HRSG) tubes and Selective Catalytic Reduction (SCR) catalysts, creating high turbine backpressure; and casing hot spots, greater than expected expansion and casing cracks.

Two common problems often encountered during inspection and troubleshooting are cold casing internal liner stud failures, and hot-to-cold casing transition cracks and hot spots. Understanding both conditions can be of material help to plant operators.

Courtesy of HRST

Figure 1: F-class turbines often have a round diffuser duct between the gas turbine and the downstream HRSG or stack

### Cold casing

Let us look first at cold casing internal liner and insulation system stud failures. The typical GT exhaust duct has internal liner plates protecting the internal insulation and one or two expansion joints that connect the duct to the turbine and the downstream ducts for the HRSG or stack.

The external cold casing is usually carbon steel. The internal liners plates are typically either SS304 or SS409 materials secured with SS304 studs. The internal insulation thickness is around six inches, which allows the external casing to operate at or below 140°F if all is working properly.

With each turbine start, this duct section must withstand a temperature change from ambient to 900+°F in seconds. As the temperature change occurs, the exhaust velocity increases to greater than 100 feet/second, with swirling turbulence.

F-class turbines, such as the GE 7F and 9F, often have a round diffuser duct between the GT and the downstream HRSG or stack (Figure 1). As fired hours and starts accumulate, so do the chances of finding broken studs in this section (Figure 2).

The studs anchor the internal liner plates and if adjacent studs fail, the internal liner plates can vibrate and liberate. This results in an immediate casing hot spot. If there is an HRSG with an SCR downstream, there is also a jump in turbine backpressure from insulation sent downstream in the direction of gas flow. The insulation commonly accumulates on boiler tubes or CO/SCR catalyst systems.

Outage inspection in the diffuser duct section is usually a matter of, "how many broken studs will be in this one?" The inspection often triggers the need for scaffold installation and broken stud repair, especially if there are multiple failed studs supporting a single liner sheet, due to the risk of liner sheet liberation.

Repairing broken studs can reveal these problems:

1. Holes in the liner sheet that the stud passes through are not aligned and are too small to accommodate plate expansion and contraction. This creates interference between the stud and liner panel

2. Large liner sheets size and expansion over the length of the sheet causes stud and hole interference

3. Poor weld fusion of the dissimilar metal weld between the stud and the scal-

Courtesy of HRST

Figure 2: As fired hours and starts accumulate, so do the chances of finding broken studs in this section


Courtesy of HRST

Figure 3: New liner system with carefully spaced studs

lop bar during fabrication

4. Broken scallop bars that weaken the stud and liner sheet support

5. Liner plate cracks propagating from the liner sheet holes.

Experience in dealing with this issue points to two solutions: Broken stud repair options to deal with repairs to keep the existing system functional; and a redesigned liner system to replace the existing design when repair maintenance and reliability risks become excessive.

Stud repair: Fixing a broken stud requires patience and planning, and often some scaffolding. The stud-to-scallop plate weld failure area must be properly exposed to check the condition of the scallop plate, repair it if cracked and weld a new stud to the existing scallop.

While performing this repair, liner plate hole alignment should be checked and improved, and holes enlarged if necessary. This process is fine for five-to-ten broken studs. But if that number keeps climbing each year, replacing the entire stud support and liner system should be considered.

Duct stud and liner upgrade: There are many factors that make for a reliable liner design. Liner sheet size controls overall expansion and contraction of the sheets during all operating conditions. Properly sized stud holes are another key factor. Ensuring that each liner stud is centered within the liner sheet hole during installation is paramount.

A robust stud design that is carefully attached to the outer shell and carefully located is critical. The design of the studs and liner plate system should control the direction for which the liner panels expand and contract during startups and shutdowns.

A retrofit was done of a 16’ diameter x 31’ long diffuser duct liner system after 12 years of cycling service. The duct is located downstream of a GE frame 7FA turbine. Prior to the retrofit, the plant had been making repairs to the original liner during every planned outage. Maintenance costs were increasing from one outage to the next. Then the plant suffered a liner sheet failure and insulation fouled an HRSG CO catalyst, resulting in a 4-inch water column (WC) increase in backpressure.

This event resulted in an outage so a repair could be made and the CO catalyst cleaned. Shortly after, the new system was ordered. Demolition of the old system revealed the full extent of the stud-weld cracking and scallop-plate cracking problems.

Installing the new system required carefully designed liner plates, studs and stud spacing in the slightly cone-shaped duct (Figure 3). Installation methodology was also important since scaffolding installation and removal had to be coordinated between the demolition phase of the top half and bottom half. These improvements reduce the risk of liner failures and lower annual maintenance costs.

## Hot-to-cold casing

The transition from the gas turbine exhaust outlet to ducting downstream can be a “trouble zone.” This area is typically a transition from a hot casing to a cold casing in a relatively short span, usually at an expansion joint (Figure 4). Temperature differentials and metal expansion in this zone often lead to casing stress and cracking.

Casing cracks then allow hot gas leakage, which causes more casing heat problems and additional issues. These include gas leaks, personnel burn hazards, insulation voids, and overheated fabric expansion joint material.

Sometimes attempts are made to “beef up” the arrangement with the addition of stiff structural members or layers of extra weld to repair cracks. This kind of “more is better” fix generally offers little help. In fact, it can worsen the situation if not applied correctly. Ironically, many expansion joints simply are not designed to adequately facilitate the hot-to-cold transition.

Another project involved an LM2500 gas turbine. Its exhaust transition piece to the HRSG gas inlet ducting had cracks. The transition duct and expansion joint had been replaced more than once.

The original design included two back-to-back flanges with heavy gussets transitioning from a small 5 ft x 7 ft inlet to a larger 6.5 ft x 9 ft outlet in the span of only nine inches. The outlet was bolted to an expansion joint transitioning from a hot casing to a cold casing.

With 850+°F exhaust gas temperatures, the carbon steel transition piece was overstressed. It suffered from chronic cracking. The expansion joint, designed only to accommodate axial movement, pulled double duty as it had to also endure extreme thermal expan-

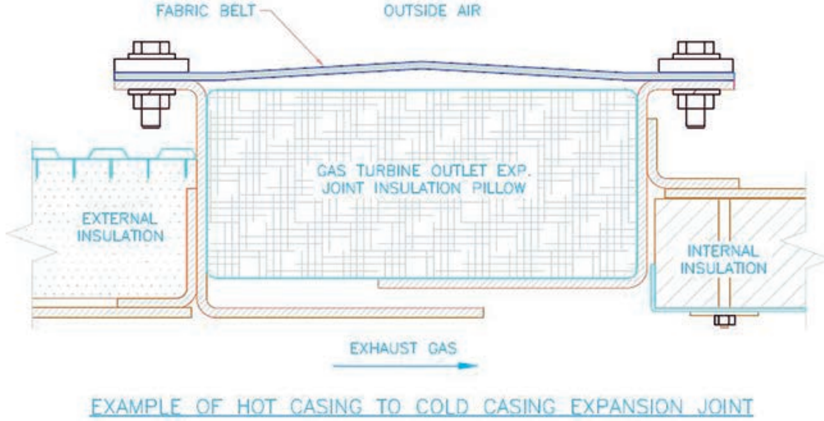


Figure 4: Hot-to-cold expansion joints often cause hot spot problems

Figure 5: New hot-to-cold transition duct

sion at the hot gas inlet.

The solution was to develop a longer transition duct allowing for a more gradual hot-to-cold casing transition (Figure 5). The duct was internally insulated from zero inches of thickness at the gas inlet to full thickness at the gas outlet.

A heavier outer casing with properly designed reinforced corners made the duct capable of managing the points where stress typically is concentrated. As there was zero insulation at the gas inlet, high temperatures to the outer casing had to be addressed.

Stainless steel was used for the outer casing in place of the typical carbon steel. The result was a duct capable of managing transient temperatures and thermal expansion. Outer lagging was attached to low rise stiffeners to help dissipate the heat from the hot casing.

The transition duct redesign also improved the expansion joint arrangement. When GT exhaust expansion joints fail, there is a high probability it can be attributed to the outside fabric being exposed to hot gas over a prolonged period.

This hot gas exposure may well come from a compressed or bunched-up insulation pillow from the many cold-to-hot-to-cold cycles. Other common issues include components that are overly stressed from excessive or transient temperatures, and components that bind up because they are not able to move freely due to thermal expansion.

Given that the new transition duct was designed with a cold casing outlet, the replacement expansion joint could be approached as a cold-to-cold design vs. the existing hot-to-cold design. This eliminated the “double duty” considerations of the previous joint.

A flexible pillow under the outer fabric was also used. The pillow could expand and compress, yet still hold its shape during hot-to-cold cycling. This avoids the creation of insulation voids that can lead to outer fabric hot spots.

Thermal breaks between the inner and outer hardware further reduce conductivity of heat to the outer casing. All components work together to reduce the operating temperature of the outer expansion joint fabric, prolonging the expansion joint longevity. ■

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GAS TURBINES

# SHALE GAS BOOSTS SINGLE-SHAFT PLANTS

## SINGLE-SHAFT DESIGNS WERE ONCE RESERVED FOR 50 HZ COUNTRIES. BUT MANY ARE NOW APPEARING IN U.S. SHALE GAS REGIONS

**BY MORGAN HENDRY**

Courtesy of Siemens

50 Hz. single-shaft combined cycle plants like the Fortuna plant in Dusseldorf, Germany are commonplace in Europe and other 50Hz. countries

Five years ago, the pattern was clear. U.S. combined cycle power plant designs strongly favored a multi-shaft arrangement, whereby the steam turbine (ST) and gas turbine (GT) each drive their own generator. Europe and other 50 Hz. countries favored the single-shaft concept: The GT and ST operate on a single shaft, share the same generator and typically have a clutch included.

Today in the U.S., however, many new plants are opting for single shaft. These facilities are largely located close to shale gas plays. In Pennsylvania, for example, several new plants are taking advantage of abundant Marcellus shale gas resources, mature gas pipeline and transmission infrastructure, and proximity to major load centers.

The Marcellus shale region encompasses over 100,000 square miles. It is the largest source of natural gas in the U.S., capable of producing more than 16 billion cubic feet per day (Bcf/d). The U.S. Energy Information Administration (EIA) projects that natural gas production in the Marcellus Shale will reach close to 150 Tcf through 2040.

Such a motherlode of gas is understandably attracting the interest of utilities and independent power producers (IPPs). They are arranging long-term gas supply contracts at favorable terms to gain a sound economic footing for new facilities. They believe that a single-shaft design gives them the best chance of profitability.

### Single-shaft studies

The first single-shaft combined cycle plant with a clutch was installed in Saarbrucken, Germany in 1972. It used two Frame 5Ns. The GTs and STs were each connected through a gearbox to a clutch and then to the generator.

From those humble beginnings, the single-shaft concept gained steady ground. There are now over 400 single-shaft units around the world, including 16 single-shaft plants in the U.S. harnessing Alstom GT24 GTs. The U.S., however, has traditionally held less than 10% of the total. But its number has risen fast in the last few years.

Part of the reason for this shift may lie in empirical results backed up by research. A study by Mahmoud Edris of the German engineering and consulting firm Lahmeyer International in 2009 *(Comparison Between Single-Shaft and Multi-Shaft Gas Fired 800 MWel Combined Cycle Power Plant*), modeled various configurations using Siemens SGT5-4000F turbines.

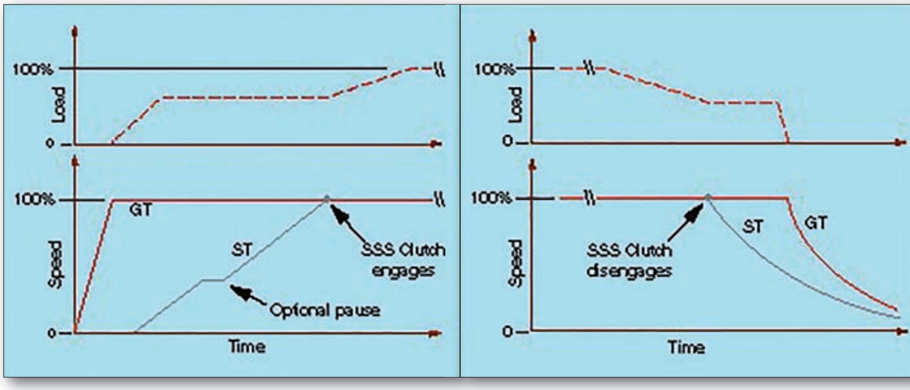



Figure 1: Operation of clutch engaging and disengaging the steam turbine from the generator

It compared the various single-shaft and multi-shaft options in terms of performance, environmental impact, space limitations and other factors. As the Edris' analysis showed, a single-shaft arrangement was more efficient for that particular GT model if only electricity was needed, but not if steam was being sold in addition.

How does it work? The basic function of the clutch in the case of single-shaft combined cycle power plants (CCPP) is to automatically engage and disengage the steam turbine from the GT/generator (Figure 1). The clutch has an input shaft with helical splines.

When the input shaft and its sliding component (ST side) reach the same speed as the output (GT/generator side), the main torque transmitting gear teeth move smoothly into mesh, thanks to an internal pawl and ratchet mechanism. The entire action is cushioned by a dashpot and dampener. Conversely, when the ST is shut down, the torque reaction within the main gear-toothed mesh is reversed, initiating automatic disengagement. The clutch also makes use of centrifugal force and oil distribution to ensure that no metal-metal contact occurs during normal operation.

## OEM Support

Turbomachinery OEMs have taken different approaches to the single-shaft versus multi-shaft debate. Mitsubishi Hitachi Power Systems (MHPS) has been building single-shaft combined cycle plants for many years, particularly in Japan as well as Mexico, Taiwan, Ireland, Thailand and South Korea.

But it is now bringing them to North America. Capital Power, for example, is adding one at its Genesee Power Plant in Alberta, Canada. Each of the two power trains will be configured in an electric generator located on a common shaft between the M501J GT and the SRT-50 ST.

MHPS will also supply the Heat Recovery Steam Generator (HRSG) for each train. This facility will add more than 500 MW and is likely to come online in 2018/2019. Capital Power said single shaft offered a significant reduction of the Genessee plant size, resulting in overall cost savings (Figure 2).

GE, on the other hand, was almost exclusively a multi-shaft provider in the U.S. until recently. Despite the fact that the company's first single-shaft CCPP went on line in 1968 and that it has both single-shaft and multi-shaft designs in its portfolio, it had reserved the former

Figure 2: Expansion of the Genesee Power Plant in Alberta, Canada is currently taking place using the MHPS M501J gas turbine in a single-shaft combined cycle configuration. This is said to result in a reduction in building size and cost savings

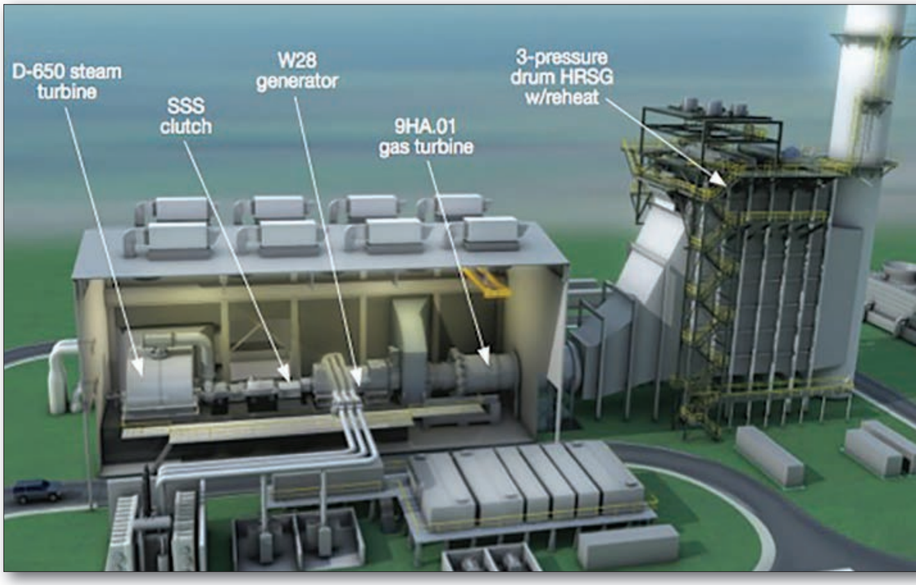



Figure 3: GE's first single-shaft FlexEfficiency plant came online in France. The company is now deploying single-shaft plants in the U.S. using its latest high availability turbines

largely for 50 Hz. territories.

GE's first FlexEfficiency 50 plant for EDF in France with a promised 61% net baseload efficiency is a good example. The 510 MW plant that recently came online uses a GE 9F 7-series GT, a D-14 ST and GE W28 generator in a single-shaft configuration (Figure 3). The company is now erecting single-shaft plants around the U.S.

## Twinning up gas plants

The Lackawanna Energy Center is an example. This 1,500 MW natural gas-fired CCPP is being developed by Invenergy. It is currently being constructed in the Borough of Jessup, Lackawanna County, Pennsylvania and is due to open in 2018.

GE is supplying three GE 7HA.02 air-cooled turbines, and related generators, CHP modules and ORC systems. Industrial Heat Transfer is providing the heat exchangers and Babcock Power is supplying three HRSGs with integrated duct burners, as well as auxiliary equipment, and an ST.

The engineering, procurement and construction (EPC) contractor for the project is Kiewit Power Constructors. CMI Energy will supply the boiler for the power plant. The facility will be selling power into PJM Interconnection.

Situated near Scranton, Pennsylvania in the North Eastern part of the state, the bulk of the natural gas supplies will be purchased from Marcellus producer Cabot Oil and Gas.

A seven-mile gas pipeline expansion project is due to be completed later this year. The availability of large quantities of nearby gas eliminates fears of high fuel prices.

Cabot Oil & Gas has secured a 10-year sales agreement to become the sole supplier to the Lackawanna Energy Center. With the EIA predicting that 45 GW of coal plants will go offline between 2014 and the end of 2021, and with many of these being in the heavily populated northeast, these new plants appear to be on a sound economic footing.

The 1,013 MW Moxie Freedom run by IPP Caithness Energy is another plant deploying GE turbines and using use natural gas exclusively from the Marcellus Shale. It is being built by Gemma Power Systems. The natural gas to power the plant will come from Cabot Oil & Gas wells in Marcellus with the pipeline and associated transmission lines close by. The power also goes to the PJM Interconnection grid.

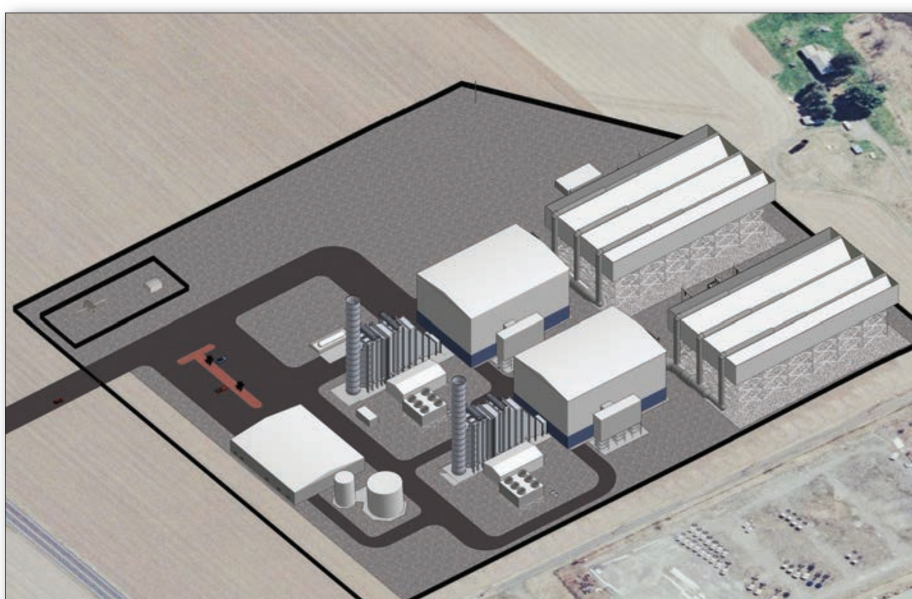
The plant's two power trains will be equipped with a GE 7HA.02 turbine, a generator, a Babcock Power HRSG, duct burners, a steam turbine, and a control system. Howden will supply air- and gas-handling equipment, and Haldor Topsoe is supplying the SCR gear. Its single-shaft combined cycle configuration gives Moxie the flexibility to run one unit while the other is offline, or based on fluctuating demand.

But this is just the start. Many more of these plants are under serious discussion. For example, GE is expected to supply the turbomachinery for what is likely to be a single-shaft facility in Renovo, PA. Bechtel plans to begin construction in 2018.

Siemens has also been establishing single-shaft plants in the region to harness Marcellus shale gas.

The Liberty Power Project in Bradford County and the Patriot plant (both 829 MW) in Clinton Township, Pennsylvania, use Siemens SGT6-8000H gas turbines in a single-shaft configuration (Figures 4 and 5). Each plant consists of an SGT6-8000H, a Siemens SST6-5000 steam turbine, a Siemens hydrogen-cooled SGen6-2000H generator, an HRSG and a Siemens SPPA-T3000 control system.

Siemens touts its single-shaft design as offering economic advantages as a result of low investment costs, smaller footprint, shorter startup times, higher efficiency and a greater flexibility during operation. These are only two of a total of seven single-shaft facilities Siemens is building in the U.S. along with Panda Power Funds (three in Pennsylvania, three in Texas and one in Virginia). When finished, these will amount to more than 5,800 MW.



Courtesy of Panda Power Funds

Figure 4: Panda Power Funds has been working with Siemens to construct standardized single-shaft facilities in regions rich in shale gas such as Texas and Pennsylvania

Figure 5: Siemens H-class technology has been deployed at the Patriot and other plants in the U.S. in a single-shaft configuration

## Which configuration is best?

Certainly, there has been a major change of heart in the U.S. as regards the deployment of natural gas-fueled CCPPs. The former dominance of multi-shaft facilities in North America seems to have swung back in favor of the single-shaft concept.

That does not necessarily mean, however, that it is the ideal configuration for all cases. There are many factors to consider including initial equipment costs, efficiency, plant use, power demand, available space, transmission capacity, steam demand and facility expansion plans, to name a few.

## A complex issue

The decision on which configuration to employ requires careful consideration. Here are a few points to ponder:

**Initial costs** — Single-shaft plants tend to be a little cheaper to build as they have fewer generators. A standardized design offers obvious design optimization advantages.

**Efficiency** — This is a complex issue. Single-shaft plants are more efficient when comparing the 1x1 configurations of each. But what about comparing multiple 1x1 single-shafts with 2x1 multi-shaft blocks? In this case, you must consider how much time the plant will operate at full load compared to partial load.

Single-shaft configurations are more efficient when demand is 50% or lower, since one unit can be completely shut down.

But if steam is in demand for cogeneration or district heating, multi shaft makes it easier to correctly size the ST and generator to match fluctuating steam availability. A curveball is then thrown when plant designers consider long-term cost of ownership, as flexibility trounces base load operation.

**Space** — 1x1 single-shaft configurations are more compact than multi-shaft. But a 2x1 multi-shaft block may have a smaller footprint than two 1x1 single-shaft trains.
s

**Transmission capacity** — The plant should be sized so it does not exceed transmission capacity. This may determine whether single shaft or multi shaft is more efficient when dealing with transmission constraints.

**Expansion plans** — Single-shaft units can be added in smaller increments than multi-shaft blocks. This makes it simpler and easier to scale a plant gradually to meet rising demand, or incrementally redevelop an existing power plant site. Once redeveloped, the assets could be financially packaged and sold to investors.

The emphasis placed on these factors will vary from site to site. Thorough analysis that takes into account the many facets and nuances of configuration selection is the only way to make an informed decision. ■

***Morgan Hendry is President of SSS Clutch Company. SSS Clutch has installed clutches in more than 400 single-shaft gas turbine plants around the world. For more information, visit www.sssclutch.com***

# MACHINERY FOR ARCTIC FLOATING UNITS

BY AMIN ALMASI

As much as 30% of the world's undiscovered natural gas and 12% of its undiscovered oil is estimated to be in the Arctic. Some of these reserves had previously been considered commercially unprofitable using older technology and based on relatively low prices of energy. But there have been efforts towards the development of technology for safe and sustainable operations in this polar region.

The Arctic is one of the most hostile working environments in existence, with prolonged darkness, snow precipitation, freezing temperatures, sea ice, and icing from sea spray. Temperatures can drop to -70°C, and there are strong winds and huge waves. The operational capabilities of traditional vessels, offshore systems and conventional machinery do not meet these requirements.

A major issue, then, is a need for regulations and guidelines on the design and winterization of Arctic vessels, offshore structures and turbomachinery. Both fixed and moored floating structures have been used in Arctic regions. Moored floating structures, employed for oil field developments and production in northern Canada, are important for future Arctic oil and gas exploration and production activities.

It is necessary, therefore, to be able to predict and mitigate marine icing of Arctic floating units. In addition, machinery innovation suitable for floating units is vitally necessary.

Floating units present design and operating challenges over those associated with fixed offshore structures, due to their dynamic response under complicated ice-structure interaction processes.

Load changes occur due to the impact from different sizes of ice (including ice ridges and icebergs), as well as the response of the vessel or structure. Incoming sea ice forms in different ways depending on structural configuration. Ice loads can be substantial. In many ways, it is similar to a conventional vessel battling the extreme forces of a hurricane.

Next generation offshore vessels are required for oil & gas production in heavy ice and harsh Arctic environments. Such a floating unit requires high-reliability operation. To counter the effects of Arctic sea ice, a well-designed floating unit is superior to other offshore options.

**The best approach for Arctic production vessels and turbomachinery may be the development of a dual- or multi-fuel steam generation system that can also be used to move compact and powerful steam drivers for vessel propulsion**

The columns and sections found on platforms or semi-submersible units attract ice loading and can become locked in ice. However, a good floating design can offer more deck load capacity than other offshore solutions. This could be looked upon as a customized floating production storage offloading (FPSO) vessel with much better protection and covering.

Arctic vessels should be largely autonomous and capable of moving under their own power. They should also operate with higher thrust and loads, and travel faster than conventional production vessels.

Such vessels must be supported by the right turbomachinery. Steam turbines are a good candidate for pumps and compressor drives. Steam generation boiler systems and steam turbine drivers have already been developed for offshore floating applications such as LNG carriers. And large submarines have experience using steam drivers in Arctic conditions.

Available technologies, then, can be deployed in Arctic production vessels. The immediate availability of cooling water can achieve relatively high efficiency for steam cycles. Additionally, steam turbines are compact and lightweight.

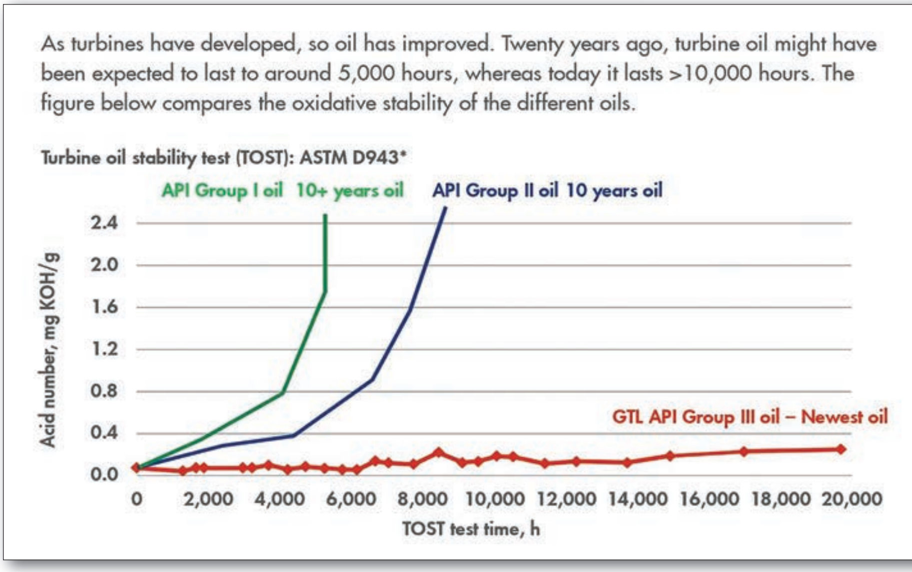
While gas turbines are efficient, inlet air could be affected by extreme weather condition. Perhaps an electric drive might be feasible. However, an all-electric solution using large generators, transformers and variable speed drive systems plus related facilities and auxiliaries could be too big and too heavy for a floating unit. But some element of electric power generation using steam turbine-driven generators would be required for any such unit.

The best approach may well be the development of a dual- or multi-fuel steam generation system that can also be used to move compact and powerful steam drivers for vessel propulsion. During production time, the steam system can be used to drive pumps and compressors using compact variable-speed direct-drive steam turbines. ■

***Amin Almasi is a Chartered Professional Engineer in Australia and U.K. (M.Sc. and B.Sc. in mechanical engineering). He is a senior consultant specializing in rotating equipment, condition monitoring and reliability.***

# HIGH-PERFORMANCE LUBRICANTS

***Dr. Peter Smith, Global Technology Manager for Shell Global Solutions in the UK, is responsible for all turbine and transformer oil development, testing and commercial support.***




Source: Shell testing data

How oils have changed over time using the turbine oxidation stability test (TOST) designed to mimic oil degradation in service

## How can Shell lubricants benefit the turbomachinery field?

Turbomachinery is placing more severe demands on lubricants than ever before. Shell power sector lubricants offer significantly higher performance compared to earlier products. They support asset life extension, reliability and efficiency optimization, and reduce the risk of unplanned shutdowns.

This includes turbine, gear, hydraulic, compressor and transformer oils, and greases to help assets operate longer. Shell also provides services and technical advice, such as oil selection, oil condition monitoring, oil storage, and change-over procedures, like flushing, draining and filling.

Turbo T, based upon conventional API group II mineral oils, has a long track record in steam and light-duty gas turbines (GTs). Our latest generation of turbine lubricants are branded: Shell Turbo S4 X for turbines, and turbomachinery that does not need higher load carrying performance; and Turbo S4 GX for geared turbines and turbomachinery requiring higher load carrying performance.

They are based upon Shell gas-to-liquids (GTL) base oil technology, which is a high-performance API group III hydrocarbon. They work in combination with a proprietary additive system to provide superior performance in steam turbines (STs) and GTs.

## What are the challenges for turbomachinery?

Turbomachinery lubricant demands are increasing: Power generation turbines operating under frequent stop-start conditions rather than continuous operation; higher operating temperatures; smaller equipment designs and lubricant reservoirs with similar or higher loads and power outputs; shock loads; fewer spared assets; increased need for asset reliability; and oil and asset life extension. These factors can place increased oxidative and thermal stress on the oil which can result in premature aging and degradation.

Further, the production of oil soluble and oil insoluble degradation products, such as varnishes and deposits can block or damage filters and bearings.

This can cause turbomachinery failure. Faster oil recirculation times can lead to increased air entrainment and cavitation issues in bearings, or foaming problems that increase bearing wear.

Accelerated oil aging is another symptom. ST oils, too, can suffer from water ingress due to poor steam seals. This can generate stable emulsions and poor bearing lubrication along with increased wear and corrosion.

## How are these issues addressed?

All lubricating oils will degrade in service over time. But products can be developed with much slower rates of degradation even under harsh conditions. Shell Turbo S4 oils have a longer lifespan as they resist degradation, thereby preventing the build-up of harmful deposits and corrosion products.

Their surface properties are another important factor. Rapid air release minimizes air entrainment even in systems with rapid recirculation. Low foaming reduces wear in bearings, as does accelerated oil oxidation. And rapid water separation is of particular value in STs due to the potential for water ingress.

## What trends relate to turbomachinery lubrication?

More than 10 years ago, most turbomachinery was lubricated with lightly refined hydrocarbon mineral oils designated by the American Petroleum Institute (API) as group I oils.

These had performance and oil life limitations. In the last decade or so, more highly refined group II oils were devised with better performance and longer life. The latest trend is highly refined group III hydrocarbons.

Shell group III GTL oils are amongst the highest performing products in laboratory and field testing. They support asset life extension, reliability and efficiency optimization, and reduce turbomachinery operational costs (Figure).

## What factors should users consider when choosing oil?

What does oil need to do in its application; what reliability and equipment life is needed; what is the oil performance specification; what performance data is available from the supplier; and can the supplier provide OEM and utility approvals, field performance data, or customer testimonials. ■

## Ceramic bearings

The Boca Bearing Company has released a line of ceramic hybrid radial bearings with deep grooves, ceramic hybrid thrust bearings, ceramic hybrid EMQ bearings, and ceramic hybrid insert bearings. These bearings are suitable for use in specialty applications, such as those seeking higher RPM's, a reduction in weight or a drop in energy requirements.

Ceramic hybrid ball bearings use ceramic balls and steel races. Ceramic balls weigh up to 40% less than steel balls, depending on size. This reduces centrifugal loading and skidding, so they can operate up to 50% faster than conventional bearings.

This means that the outer race groove exerts less force inward against the ball as the bearing spins, cutting down friction and rolling resistance. The lighter ball allows the bearing to spin faster, and uses less energy to maintain its speed.

Ceramic silicon nitride balls exhibit greater hardness than steel balls resulting in at least ten times greater ball life due to the ability to hold the surface finish longer. The ball has smoother surface properties than the best steel ball, which means less friction.

Improved thermal properties lead to less heat buildup at high speeds. Compared with steel, ceramic has 35% less thermal expansion, 50% less thermal conductivity, is lighter weight and non-corrosive.

The inner and outer races of antifriction bearings often become frosted, fluted, or can be imprinted with a corrugated pattern. These are not mechanical scars but are due to electromagnetic forces and can lead to bearing failure.

Such problems are usually found in modern systems that routinely feature pulse-modulated, adjustable-speed motors and inverters with high switching frequencies and short rise times. By substituting ceramic hybrid bearings for their chrome steel counterparts, it is possible to eliminate pitting and scarring, and run cooler due to less micro-weld adhesion.

Suitable applications for ceramic hybrid or full ceramic bearings include cryopumps, medical devices, semiconductors, machine tools, turbine flow meters, food processing equipment, robotics and optics.

*bocabearings.com*

## Ultrasonic flow system

Siemens new digitally based Sitrans FS230 clamp-on ultrasonic flow system is a combination of the Sitrans FST030 transmitter and Sitrans FSS200 clamp-on sensors. It is suitable for industries requiring high-quality liquid flow measurement.


The Voith VECO-Drive steps up input speed and generates a high output speed for compressors or pumps. Since additional power is supplied to the drive train, a smaller main motor can be used for this variable speed drive

It includes a Digital Sensor Link that digitizes the signal at the earliest stage of measurement, resulting in an optimal signal-to-noise ratio. Due to its 100 Hz data update rate and integrated Performance-PLUS algorithm, the transmitter detects tiny changes in flow. It also offers diagnostics that detect changes in aeration, signal quality, sonic speed, temperature and fluid type.

*siemens.com*


TMEIC's variable frequency drives such as the Dura-Bilt5i MV have been outfitted with a new electronic control board

## Electric drive controls

Toshiba Mitsubishi-Electric Industrial Systems Corporation (TMEIC) has introduced an electronic control board set for its family of variable frequency drives (VFDs). The control board set is designed for faster processing speed and data communications using floating point calculations. It responds to industrial communication protocols such as ProfiNet, Modbus RTU, CC-Link, EGD, and TCnet-IO, as well as supporting Ethernet 100Base-T for high-speed communication. A support tool known as TMdrive-Navigator gives extended data monitoring and reduces troubleshooting time. All TMEIC drive families are available with TMEIC's remote connectivity module (RCM.)

RCM allows operators to remotely connect to the drive and monitor its performance. Common applications for drives include supplying power to variable speed motors driving pumps, compressors, fans, extruder, mixers, and crushers used in oil and gas, water and waste-water, mining, power generation, paper, cement, and petrochemicals.

*TMEIC.com*

## Variable speed drive

The Voith VECO-Drive is the first member of a new product family in the field of speed control for compressors and pumps. It is an electric superimposing gear, inspired by the established principle of the Voith Vorecon with more than 600 installations.

The VECO-Drive combines a mechanical planetary gear with frequency-controlled servo motors. The electrical superimposing gear is an efficient way to make speed variable.

Servo motors are used to drive a planetary gear. Since they only need a small part of rated power, an overall component efficiency of more than 97% is reached. This saves energy and reduces operating expenditures.

Servo motors are installed between a constant speed motor and a variable speed compressor or pump. This combines the reliability of mechanical gears with the productivity of low-voltage variable frequency drives (VFDs). Since additional power is supplied to the drive train, a smaller main motor can be used, saving capital expenditures. The servo motor can be used as a starter to protect the electric grid from high inrush currents.

A prototype system was built and tested in Crailsheim, Germany. It was designed for compressor and pump ap-

Cortec MCI technology provides corrosion protection for reinforcing metal in concrete, rehabilitating existing concrete structures as well as extending the life span of new structures

plications with a maximum output speed of 15,000 rpm, maximum output power of 15 MW and a speed adjustment range from 50% to 100%.

The VECO-Drive has about 2% higher efficiency compared to a typical full-scale medium voltage VFD train with a step-up gearbox over the whole speed range. This equates to an annual energy reduction of more than 2,000 MWh.

It is a modular system with individual specifications for different application types, classes of explosion protection and speed levels. Functions like the integrated PLC-based output controller, user interfaces, condition monitoring and simplified maintenance are part of the scope of supply, whereas remote access and remote diagnosis are available on demand.
*voith.com*

## Centrifugal disk finishing

Previously, the removal of burs and sharp edges on thin, relatively small parts required the use of centrifugal disk machines with special spinners made from ceramic or tungsten carbide steel. To prevent thin parts getting caught in the gap between the rotating spinner and stationary work bowl, the precise setting of the gap was crucial.

Since even minor damage to the spinner could result in high repair costs, Walther Trowal developed the Turbotron gap rinsing system to eliminate spinner damage and adjust gap size. The pressure created by the rinsing system ensures that thin parts can no longer be drawn into the gap between spinner and wear ring.

These machines operate with a high water level in the work bowl. This helps prevent the work pieces from sticking to each other or clinging to the wall of the work bowl. The spinner and wear ring are made from polyurethane.
*walther-trowal.com*


Wireless sensors in the Trico Sensei transmit oil level and air temperature data

## Corrosion protection

Cortec MCI-309 is a vapor-phase corrosion inhibitor powder for protection of ferrous metals and aluminum in recessed areas, interior cavities and voids. It provides an efficient dry method of protecting metals.

It vaporizes and absorbs on the metal surfaces, reaching all exposed areas and interior cavities. This mixed inhibitor provides protection to both the cathodic and anodic metals. MCI-309 does not affect the physical properties of concrete or grout (set time, strengths, and so forth) and it is safe for high tensile strength steel (will not cause hydrogen embrittlement).

Corroding rebar in deteriorating concrete often causes costly repairs, financial losses and serious injuries. MCI technology can prevent this.

It creates a monomolecular inhibiting layer and enables up to 24 months of continuous protection. Protected surfaces do not have to be cleaned prior to concrete or grout placement. If the MCI layer is disturbed by moisture or by opening the enclosed space, the layer is replenished by continuous vapor re-deposition. It does not contain silicates, phosphates, nitrites or heavy metals.
*cortecvci.com*

## Smart lubrication

Trico has introduced Sensei, a real-time lubrication intelligence system. It wirelessly transmits oil level and ambient air temperature to a web-based dashboard. Users gain real-time input on machine status and maintenance requirements.

This can reduce inspection time, eliminate the need to

ITT's i-ALERT sensor

visit difficult- or dangerous-to-access areas, avoid downtime by providing alerts and warnings, and facilitate proactive maintenance.

The first wireless sensors available as part of the Sensei system are oil level sensors designed to accompany Trico's line of 8-oz. Opto-Matic vented and closed constant level oilers.

Pumps, motors, gearboxes, fans, blowers and other equipment use constant-level oilers to maintain a consistent fluid level. Industrial and manufacturing applications include those in machining, petrochemicals, chemical processing, primary metals, pulp and paper and power generation. The Sensei system includes three components: An oil sensor, a router that securely receives data and transmits it to the cloud, and a customizable dashboard display.

*tricocorp.com*

## Industrial IoT platform

ITT's PRO Services brand unveiled the i-ALERT Ai platform, a web interface allowing customers to take advantage of the Industrial Internet of Things (IoT) to monitor all their i-ALERT2 enabled rotating equipment in one place. The simple online platform followed on from the i-ALERT2 Bluetooth Smart-enabled machine health monitor. Together, they enable users to spend less time collecting data from rotating equipment.

This subscription service requires no software to download or dedicated hardware to run. It offers trend data, machine notes, technical data and vibration spectrum data collected via the i-ALERT2 app) visualized on a timeline. The company's IoT sensor is compact (57 mm L x 39 mm W x 26 mm H / 2.23 in L x 1.53 in W x 1.02 in H). ITT's i-ALERT2 monitor combines the latest in Bluetooth low-energy and sensor technologies.

*i-alert.ai*

## Real-time material rendering

Kisters North America has released version 2017 of its 3DViewStation Desktop, a 3D CAD viewer. Its updates include a real-time materials rendering function, high performance viewing, advanced analysis and integration capabilities. It ships with a broad range of importers for 3D and 2D formats.

*kisters.de*

## 3D printing

Businesses are becoming increasingly aware of the opportunities that additive manufacturing (AM) offers. The global AM market (also known as 3D printing) has seen annual growth rates of 20 to 30 % since 2010. According to a study by international management consultancy firm Bain & Company, this trend will accelerate in the years to come.

SLM Solutions offers a range of 3D printers featuring industrial-class Selective Laser Melting (SLM) technology. It has a proven track record in industries, such as aviation & aerospace, in making components. These are used for prototypes, small series and individual series products. They offer greater productivity, flexibility and the opportunity to reduce lead time.

*slm-solutions.com* ■

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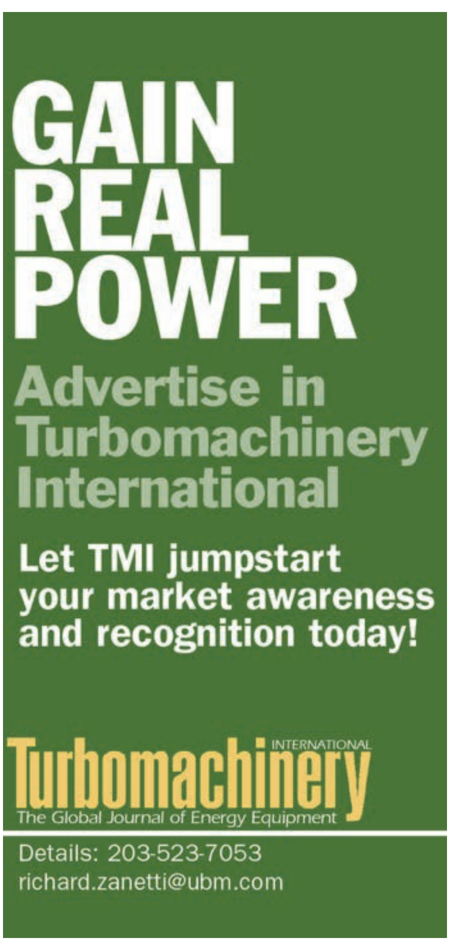

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# MYTH: DEVELOPMENT PATHS FOR NEXT-GENERATION POWER PLANTS (Part 1)

**BY KLAUS BRUN & RAINER KURZ**

Over the last couple of years, researchers have published many papers addressing the need for increased efficiency from gas turbines (GTs) and combined cycle power plants (CCPPs). This discussion was primarily driven by greenhouse gas (GHG) emission reductions and improved utilization of limited hydrocarbon resources.

Both topics have somewhat lost relevance due to: Advances in oil & gas production technologies that have made hydrocarbons abundant again; and GHG mitigation taking a political backseat. Nonetheless, it is worthwhile to review and analyze technology options for efficiency improvement alternatives and estimate their commercial viability.

Current state-of-the-art large utility-scale CCPPs reach efficiencies slightly above 60% for favorable heat-sink cooling conditions. Government agencies and industry associations have stated a goal to improve this efficiency to 65% over the next 10 years. But keep in mind that we have seen diminishing efficiency gains over the last decade compared to previous development cycles.

Between 1960 and 1970, simple cycle GT plant efficiency increased from about 18% to 32%. With the introduction and wide commercial acceptance of CCPPs between 1970 and 1985, efficiency jumped to approximately 55%. Subsequently, F-class plants had reached about 58% efficiency by 1995.

Since then, improvements have been in the low single digits. For example, the first GE Frame H CCPP started commercial operation in 2002 (Baglin Bay, UK) and achieved near 60% efficiency. After that, marginal improvements to around 61% have been realized by the newest G, H, and J class GT plants. In other words, the efficiency improvement is 1.5% at best for the past 15 years. Clearly, adding another 4% over the next 10 years is highly ambitious and not necessarily credible.

The current OEM approach for improved efficiency is through firing temperature and pressure ratio increases. Better materials, coatings and advanced blade cooling schemes are the main contributors.

From a fundamental thermodynamic perspective, a Brayton cycle's pressure ratio has the greatest impact on efficiency while firing temperature primarily drives output power. But both parameters are tightly related so both need to be raised to improve performance. The physical relationships are slightly more complex in CCPPs since GT exhaust temperature and thus firing temperature have a strong impact on the efficiency of the bottoming steam Rankine cycle.

**Adding another 4% combined cycle efficiency over the next 10 years is highly ambitious and not necessarily credible**

Is faster and hotter the right answer? The latest generation of GTs operate at firing temperatures exceeding 2,800°F and require nearly 10% of the compressor flow for hot section cooling. Their hot section turbine blades are made from high-nickel alloys and use complex internal and external cooling and thermal barrier coatings to keep the base metal temperatures within allowable limits.

Nonetheless, all modern GTs operate near their material cyclic stress failure and creep life limits. To obtain increased pressure ratios, higher blade speeds are necessary. To gain more power, higher firing temperatures are required.

Unfortunately, GTs with faster blade speeds, either through higher rotational shaft speeds or larger blade tip diameters and hotter combustion (for higher heat source temperatures), are fundamentally limited by current material technology options. And there is little indication that improvements in novel metal alloys will lead to drastically higher allowable metal temperatures and yield stresses in the near term.

Hand calculations show that to arrive at 65% combined cycle efficiency using evolutionary steps from today's industrial frame engine technology, GT firing temperature will have to be around 3,100°F, pressure ratio must be well above 25, and the hot section cooling flow requirements will have to be reduced to less than 6% of compressor flow.

To get there, we have seen some promising developments using ceramics and ceramic matrix blade materials. But most of these suffer from other physical property shortcomings, such as brittleness and lack of impact resistance. This makes them difficult to implement in GT components.

Significant improvements have also been made in compressor and turbine aerodynamics using computational fluid dynamics to develop complex 3-D blade shapes. However, these improvements contributed far less to plant performance enhancements than the gradual increase of firing temperature and pressure ratio. Part 2 will appear in the next issue. ■


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FROM RELIABLE EFFICIENCY TO KEEPING THE LIGHTS ON
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Power companies are under immense pressure to keep the lights on. As a result, modern turbine oils must be able to cope with increased stress and considerable design and operational challenges. Although selecting an underperforming lubricant rarely results in immediate failures, it can lead to long-term increases in maintenance costs and heavy power-outage penalties. In contrast, adopting a total-cost-of-ownership[1] approach with a high-performing lubricant from the Shell Turbo range can help to reduce costs by unlocking reliable efficiency. Ask us how we can work with you to make it possible.
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[1]Total cost of ownership is defined by Shell Lubricants as the total amount spent on industrial equipment, including the cost of acquisition and operation over its entire working life and the cost of lost production during equipment downtime.