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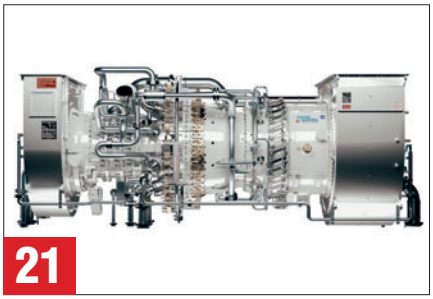

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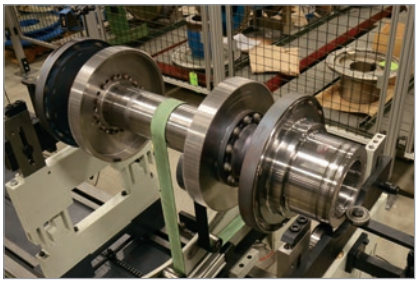

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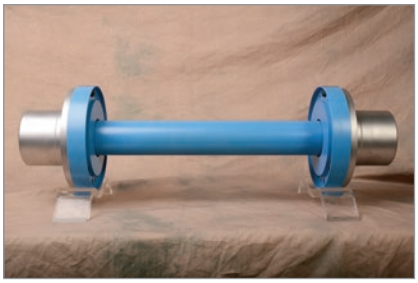

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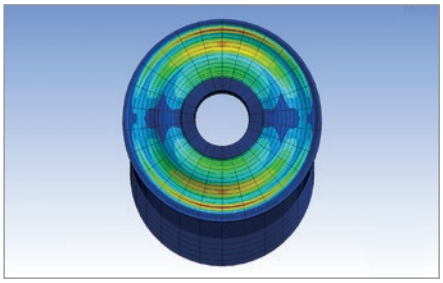

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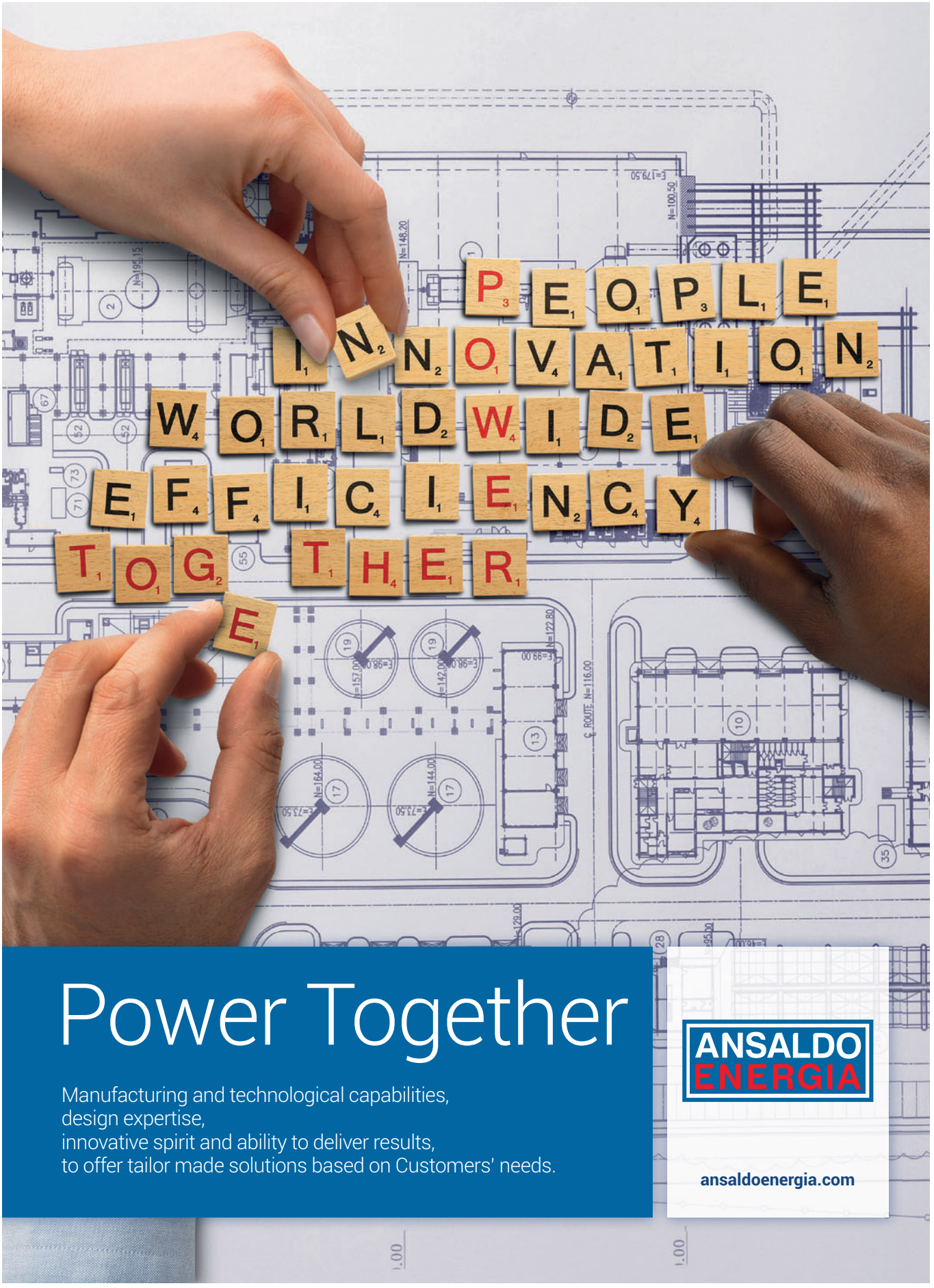

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CYBERSECURITY AND DIGITALIZATION

Our cover story Surviving Digitalization is about the importance of cybersecurity. Anyone digitalizing their business will be in serious trouble if they don't follow the advice in this article about security. The biggest companies in the world, the most tech-savvy and security-savvy giants out there are struggling to keep the bad guys out. Many lessons can be learned from their experience.

> **"Just as cash has been largely replaced by plastic, old ways are being replaced by digitalization"**

Yes, there are plenty of benefits to be reaped from digitalization. But for every plus, there is a cybersecurity menace lurking. What we may see are three possible futures for industrial companies confronting digitalization:

- Those who naively charge ahead, oblivious to security
- Those who take bold steps into digitalization supported by comprehensive security measures
- Those who cower in the corner, too afraid of possible negative consequences to modernize their infrastructure.

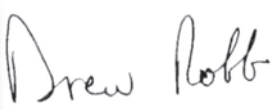
The first group you will be hearing about via embarrassing headlines on how they opened the enterprise to malware and severe data breaches. The second group are positioning themselves to assume the mantel as the leaders of tomorrow. The third group you may not hear much about at all.

Certainly, there are disturbing headlines around about CEOs being defrauded of funds in online scams, ransomware shutting down access to corporate systems, intellectual property theft, and millions of identities stolen. But there is an important point that is often missed. None of the companies defrauded, ransomed, or robbed retreated from the internet. They each beefed up security and continued their online digitalized approach.

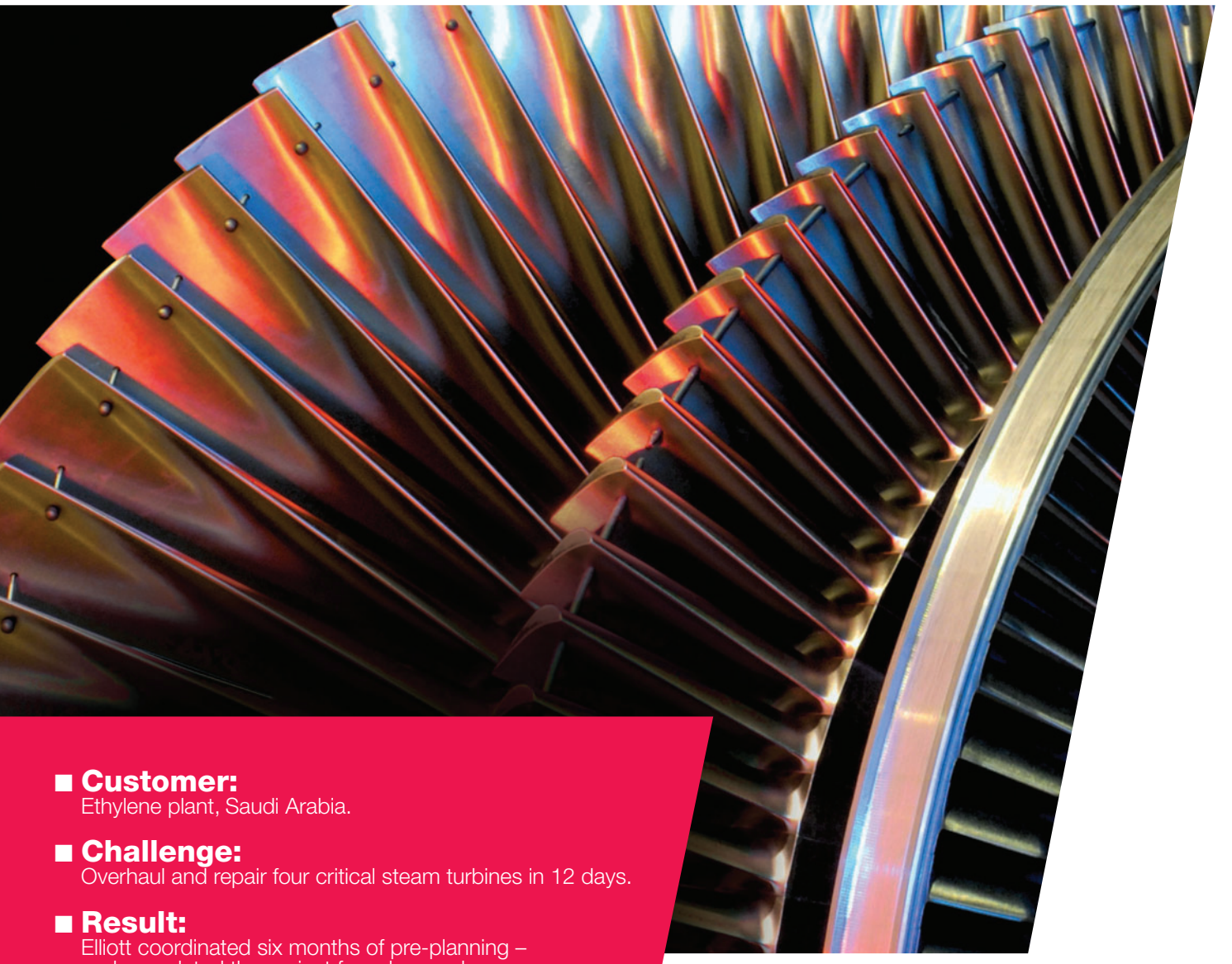
The reason is simple: this is how business is evolving. It has become almost impossible to operate in the modern world without credit cards or debit cards. It will become increasingly difficult for traditional industrial businesses to find customers, partners or suppliers if they don't modernize. Just as cash has been largely replaced by plastic, old ways are being replaced by digitalization. But cybersecurity must be implemented in parallel with digitalization, not as an afterthought.

The rest of this issue contains stories on compressor upgrades, a project that is harnessing an all-hydrogen gas turbine, the latest on Elliott turbomachinery, how to extend mean time between overhauls, and columns about FPSOs and polytropic efficiency.

By the time you read this, we hope the ravages of a late winter are over and spring is blossoming. ■



DREW ROBB
Editor-in-Chief



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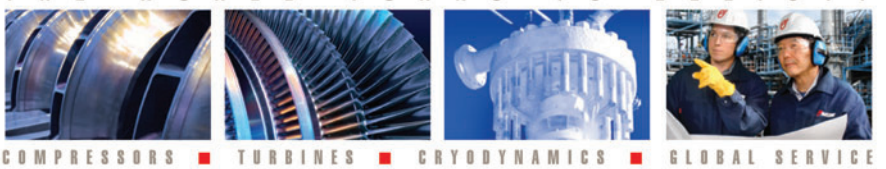

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MHPS achieved market leadership in 2018 for GTs of 100 MW or above

Power generation dominance

Mitsubishi Hitachi Power Systems (MHPS) secured 2018 market share leadership in global orders for heavy duty gas turbines (GTs) (100 MW and above). The result is based on data compiled by McCoy Reports. This was driven by the J-Series GT. MHPS captured 41% global market share in this segment of the market. For post F-class and larger GTs, MHPS scored 49% market share.

While GE (28%) was second behind MHPS for larger machines, GE leads overall in GT orders for power generation in 2018. Siemens gained 25% of orders for GTs above 100 MW. For orders above F-class, GE recorded 34% and Siemens 16%. For F-class, GE led with 33% of orders by capacity, MHPS had 31% and Siemens had 26%.

ATP Industry Summit

The Asia Turbomachinery & Pump Industry Summit (ATP Industry Summit) is a two-day information-sharing, training and networking event for practitioners in rotating equipment and related fields. The event is set for July 10–11, 2019, at the Kuala Lumpur Convention Center in Malaysia. It is free to attend with no pre-registration necessary.

Single-subject intensive short courses will be held in conjunction with the summit on July 8–9. Short courses will have a registration fee, and preregistration is encouraged as space is limited.

The ATP Industry Summit is intended to support the biennial ATPS, slated for spring 2020. The ATP Industry Summit will not include an exhibition. Petronas and Mitsubishi Heavy Industries will deliver keynotes. Lectures will examine industry trends along with products and processes that focus on current and future industry. The program includes two panels, a tutorial, and eight case studies.

TMEIC unit

TMEIC has merged two business units to form an Energy and Infrastructure Solutions Business Unit (E&IS BU). TMEIC also announced that Manmeet Bhatia, General Manager Global Drives BU, has been named TMEIC Chief Operating Officer.

Lubrication acquisitions

RelaDyne, a provider of lubricants, fuel, diesel exhaust fluid (DEF), and industrial reliability services, has acquired Rachel Oil Company, a lubricant and fuel distributor based in Mansura, LA. As part of RelaDyne, Rachel Oil plans to grow and expand with access to RelaDyne brands and products.

RelaDyne also acquired Circor International's Reliability Services division, operating under the brands of Cot-Puritech, Clarus, LSC, Lubritech, Sicelub and Canadian Chemical Cleaning Services. The division provides lubrication management, chemical flushing services, and oil misting equipment.

The division was acquired by Circor International as part of the acquisition of the Colfax Fluid Handling Business completed in December 2017. Cot-Puritech is a provider of specialty flushing and preventative maintenance services, primarily to the processing and industrial end markets in North America.

Clarus Fluid Intelligence provides specialty flushing and preventative maintenance services to the U.S. Navy and defense end markets. Lubrication Systems Company is a provider of automated and control lubrication equipment sales and installation, aftermarket equipment support, and private-label lubrication.

Sicelub, with Lubritech, is a provider of specialty flushing services and preventative maintenance as well as control lubrication equipment to the South American and European markets. Canadian Chemical Cleaning Services provides high velocity oil flushing and chemical cleaning to all industrial sectors across Canada.

Bioethanol power

A peak-load GT operating primarily on bioethanol in Saint-Pierre, Réunion Island, has been commissioned by Albioma, a French renewable energy producer. It works on bioethanol (80%) from the distillation of sugarcane molasses, produced locally, and diesel fuel (20%), which is needed to start the turbine. The 41 MW GT starts in less than 7 minutes.

Continues on page 10

Rockwell digest

Rockwell Automation and Schlumberger are creating a joint venture called Sensia, said to be the first fully integrated digital oilfield automation solutions provider. The transaction is expected to close in the summer of 2019.

It will be an integrated provider of measurement solutions, domain expertise, and automation to the oil and gas industry. It will offer scalable, cloud and edge-enabled process automation, including information and process safety solutions. From intelligent systems to lifecycle management automation, the joint venture will help drive efficiency gains.

Sensia will operate as an independent entity, with Rockwell Automation owning 53% and Schlumberger owning 47%. Sensia is expected to generate annual revenue of $400 million and will employ about 1,000 in more than 80 countries, with global headquarters in Houston, TX.

The management team will be led by Allan Rentcome, who will serve as Chief Executive Officer. He is currently Director Global Technology, Systems and Solutions Business at Rockwell Automation.

Rockwell Automation has acquired Emulate3D, an engineering software developer whose products digitally simulate and emulate industrial automation systems. Emulate3D's software enables customers to virtually test machine and system designs before incurring manufacturing and automation costs and committing to a final design.

Rockwell Automation will add Emulate3D's technology to its digital design portfolio to deliver solutions to automotive, logistics, material handling, and other industrial applications. Software will be sold as Emulate3D by Rockwell Automation, as part of Rockwell Automation's FactoryTalk DesignSuite.

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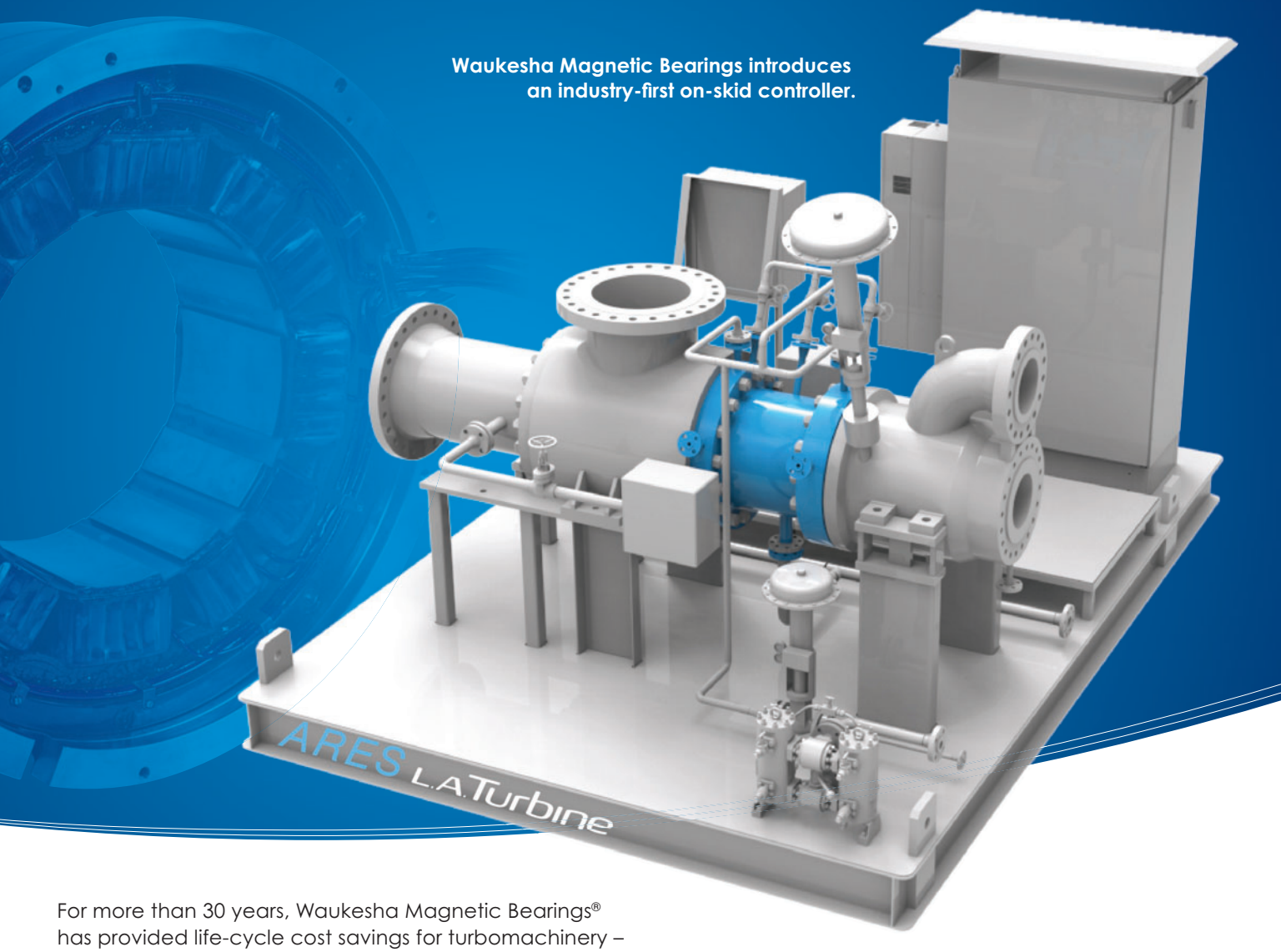

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Siemens digest

The Siemens H-class GT has been on the market for nearly a decade and has now exceeded a million fired hours. With 70 turbines in operation on four continents and almost 100 machines sold, the SGT-8000H has an output of 450 MW, with over 61% combined cycle efficiency.

The SGT-8000H achieves low NOx emissions over a wide load range, and is flexible, thanks to its load-following capability of 60 MW/minute (SGT6-8000H for 60Hz)/ 80 MW/minute (SGT5-8000H for 50Hz).

Siemens has signed an extension of a multi-year maintenance service agreement with Shuweihat S2 Operation and Maintenance Company (S2O&M). Siemens will support the 1,500 MW combined cycle power plant (CCPP) and water plant, Shuweihat S2 IWPP in Abu Dhabi, United Arab Emirates.

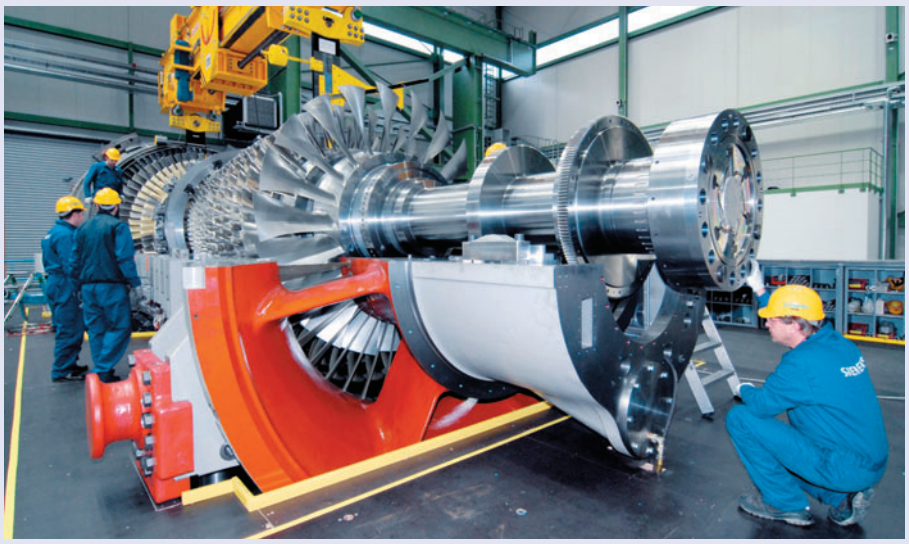
With the 18-year extension, Siemens will also deploy products from its Omnivise digital services portfolio including cybersecurity to improve asset visibility, reliability and availability. Siemens' FlexLTP (Flexible Long-Term Program) provides asset availability by extending intervals between inspections.

Using analytics, it provides a visualization of plant asset data and key performance indicators (KPIs) for early detection of potential issues. The agreement will also cover supply of spare parts, on-site inspection and major inspections on Siemens SGT5-4000F GTs, SST5-6000IP steam turbines (STs) as well as associated generators and electrical equipment.

Siemens has secured an order for the re-powering of Cooperative Energy's R.D. Morrow, Sr. Generating Station facility in Purvis, MI. It will use Siemens HL GT technology to re-power the existing coal-powered STs. The CCPP will have a capacity of 550 MW. Cooperative Energy will upgrade a coal-fired generation unit with a Siemens SGT6-9000HL.

The scope of supply also includes an SGen6-3000W generator and the SPPA-T3000 control system. Siemens has also been awarded a long-term service agreement. The contract includes service on parts, repairs, field services, program management, and offerings from the company's Omnivise Digital Services portfolio, including remote monitoring and diagnostics.

Siemens received an order to supply the Duqm Integrated Power and Water project (DIPWP) in Oman with GTs and STs, long-term power generation services and digital solutions. Following completion of the project in 2022, DIPWP will have an installed generating capacity of 326 MWs in combined cycle and 36,000 cubic meters of desalinated water for Duqm refinery and petrochemical facilities per day.



Siemens H-class turbine has exceeded one-million fired hours of operation

Scope of supply includes a CCPP consisting of five SGT-800 GTs, five SST-300 STs, and a control system. Siemens' cybersecurity solutions will also be used.

Siemens will provide four ST generator sets and auxiliary equipment for a 700 MW concentrated solar power (CSP) project in Dubai. The facility will be the largest single-site CSP plant in the world and comprises phase four of the Mohammed Bin Rashid Al Maktoum Solar Park.

Solar steam turbines

It includes three solar STs with a power output of 206 MW each for three parabolic trough units and another solar ST with an output of 108.5 MW for one central tower unit. The first phase of the CSP project will include one 206 MW parabolic trough unit and the 108.5 MW central tower unit. It is scheduled to be commissioned in 2020.

Siemens was selected to supply two SGT-300 industrial gas turbines for an established Montney shale producer in Alberta, Canada. The equipment order, placed by the customer's EPC firm, marks the first application of an SGT-300 turbine in Canada.

The gas processing plant will help support production growth for the customer in the Grande Prairie Region, located northeast of Edmonton, and will be built alongside the company's existing dehydration and compression facility. When completed in 2020, the plant will provide an additional 50 million cubic feet per day of natural gas processing capacity and 30,000 barrels per day of condensate stabilization capacity.

Siemens is supplying two SGT-300 GTs in a non-enclosed design, allowing the plant-wide fire detection and suppression system to ensure worker safety throughout the facility. It will also provide open access for maintenance and visual inspections.

Siemens has signed an extension of a long-term service agreement with Qatar Power Company (QPOWER) to maintain and support the power generation requirements of Ras Laffan B CCPP for an additional 15 years.

It will provide maintenance, parts and repair services for three SGT5-4000F GTs, two SST5-6000 STs, and their associated generators. In addition, the agreement includes digital services and cybersecurity solutions.

The company is providing one feed and sales gas train and one refrigeration compression train for Encana's Pipestone Processing Facility in Grand Prairie, Alberta, Canada. Designed to accommodate future capacity expansion, the Pipestone Processing Facility will provide Encana with 19,000 barrels per day of net raw condensate processing capacity plus 170 million cubic feet per day of net inlet natural gas processing capacity.

Keyera will own the Pipestone Processing Facility and provide processing services to Encana. It will have a capacity of 200 million cubic feet per day and is expected to start up in 2021.

The first train will consist of a Siemens SGT-750 GT driving two Dresser-Rand DATUM compressors for feed and sales gas compression, combined with a Siemens waste heat recovery unit for process heat. The second train will consist of a Siemens electric motor-driven Datum compressor for refrigeration compression with Siemens variable frequency drive.

Howden's Houston service center

Howden service center

Howden has completed the move to a new 35,000 square foot service center in Houston, TX. The center can service centrifugal fans, cooling fans, air preheaters, reciprocating compressors, blowers, centrifugal compressors and screw compressors.

This includes brands, such as Roots, Thomassen Compression Systems, Turblex, ČKD Kompresory, American Fan, Garden City, Covent, Buffalo Forge, American Standard, and Westinghouse Sturtevant. The center contains three 20-ton overhead cranes, nine 2-ton jib cranes, balancing equipment, a component repair bay, welding bay, paint booth and ample testing space.

Biomass plant

The German biogas plant manufacturer Weltec Biopower has begun construction of a biomethane plant near Pontefract, West Yorkshire, UK. The client is Lanes Farm Energy, a gas-to-grid project developed by Aqua Consultants. The plant will go live in late 2019 and deliver 7.3 million m^3 of biomethane to the UK gas distribution network.

Food leftovers, cattle and chicken manure as well as grass silage and hybrid rye will fuel the plant. Gas production will take place in four stainless-steel digesters with a height of 8.8 m and an above-average capacity of 6,848m^3 each.

Weltec will use membrane upgrading to transform the biogas into high-quality biomethane. In a separation process comprising several stages, the raw biogas will be refined without methane slip. In this way, 850 standard m^3 of biomethane that is suitable for feed-in will be produced every hour from December 2019 on.

Additionally, the biomethane production will yield digestate, which can be used as fertilizer, returning organic material and nutrients to the land. A pasteurization unit will be equipped with a heat recovery system. For on-site electricity supply, Weltec will integrate a 500 kw CHP unit. The operator will generate additional income from exporting excess electricity to the grid.

New biogas plant for England

Continues on page 12

GE digest

GE and Sumitomo are teaming up to develop, build and operate a 1.8 GW CCPP in the United Arab Emirates. The Sharjah Electricity and Water Authority (SEWA) has signed a 25-year power purchase agreement with GE and Sumitomo.

The plant will feature three GE HA GTs, three STs, six generators and three heat recovery steam generators (HRSGs). GE also will supply EPC services for the plant in the city of Hamriyah, Sharjah, as well as supplying parts, repairs and maintenance over the 25-year period.

Leonardo DRS will continue to manufacture GE-designed LM2500 packages for U.S. Navy and selected international platforms until the end of 2024. The agreement includes an option to extend the supply deal through 2029.

The company provides the baseplate, enclosure, and a fully instrumented, wired and piped package for the three LM2500 engine sizes, LM2500, LM2500+ and LM2500+G4.

GE Power has provided a 9E GT to the Ministry of Electricity's (MoE) Al Qudus Power Plant in Iraq. GE will also service up to seven GE 9Es at the facility throughout 2019, including maintenance, supply of parts and rehabilitation. The new turbine is expected to generate up to 125 MW.

GE will service nine GTs as part of an extended service agreement for an industrial power plant in Thailand. PTT Global Chemical signed the 10-year extension to its existing agreement. GE will service six 6B and three Frame 5 GTs at the Map Ta Phut Industrial Estate power plant in Rayong, Thailand. GE also will provide its Asset Performance Management (APM) software as part of GE's Digital Energy portfolio.

In alignment with the trend of decoupling steam production from power production in Combined Heat & Power (CHP), Novel S.p.A. turned to GE Power to modernize its power station in Novara, Italy. GE will upgrade its GE GT with an array of Fleet360 services to increase power and steam for the industrial process at Radici Chimica's chemical plant.

The surplus power will be sold to the grid. GE will install its APM software that includes predictive maintenance capabilities and 24/7 remote monitoring. GE also will provide its DLN 2.6 combustion system with Mark VIe controls. The upgrade should be completed by late summer 2019.

GE Marine will supply GT auxiliary equipment for the LM2500 engines to power the Indian Navy's new P17A frigates. This contract is with India-based Mazagon Dock Shipbuilders Ltd. (MDL) and Garden Reach Shipbuilders and Engineers Ltd. (GRSE).

GE will provide equipment for seven ships to support the 14 LM2500 engines previously supplied under a separate contract. Auxiliary equipment and services will include: GT controller, intakes and uptakes, firefighting equipment, water wash, start skid, fuel forwarding and field service support to shipyards. Electric starters for the GTs will be included. Each frigate will be powered by two GE LM2500 marine GTs and two diesel engines in a combined diesel or GT configuration.

Taiwan Power Company (TPC) has awarded the DaTan 8&9 power project to the GE-Marubeni consortium. Located in Taoyuan City, the plant will be powered by four GE HA turbines and is expected to generate over 2,000 MW.

BHGE contract

Baker Hughes GE (BHGE) has been awarded the first part of a contract for six turbine control upgrades at Bruce Power, the largest operating nuclear power facility in the world. The contract includes Mark VIe turbine controls, as well as BHGE's Bently Nevada condition monitoring technology, Security ST cybersecurity protection suite, and turbine simulator software.

With more than 47 terawatt hours of electricity produced annually, Bruce Power's Ontario facility is being upgraded to full digital analytic capability to enable greater efficiency. These control upgrade packages will help to extend the life of Bruce Power by 40 years.

Ansaldo contract

Edison and Ansaldo Energia signed a contract for the Marghera Levante CCPP. The power islands are to be made up mainly of the Ansaldo GT36 GT. The plant will have a capacity of 780 MW and energy efficiency of 63%.

Continues on page 14

MAN MGT6000 gas turbine

MAN Mopico compressor

MAN digest

Four MAN Energy Solutions GT trains were delivered to Chinese cogeneration plants. The two low-emission GT packages comprise MAN's THM series as well as an MGT6000 GT. As part of a CHP system, these machines deliver around 17 MW of power and 35 MW of heat to an industrial park in the provincial capital of Changsha.

The packages replace a coal-based plant. Another MAN MGT6000 package has begun commercial operation in a CHP plant in Dongguan City (Guangdong Province). In addition to about 6 MW of electricity, it will provide 13 MW of heat.

MAN Energy Solutions Switzerland has won an order within the Baltic Energy Market Interconnection Plan (BEMIP). As the next step in integrating the Baltic states Lithuania, Latvia and Estonia into the European energy grid, the Balticconnector pipeline is part of BEMIP.

This pipeline will ensure the connection of the Finnish and Estonian gas grids. Starting in the Finnish town of Siuntio, it runs to Ingå (Finland), continuing underwater to Paldiski and stretching via Kiili to Puiatu (all in Estonia).

The order includes two MAN Mopico RM40 compressors with a MAN M33 motor each and a corresponding Active Magnetic Bearing (AMB) System supplied by MAN-owned Mecos. In addition to the compressor systems, the scope includes delivery, planned for summer 2019, as well as commissioning. The unit for Paldiski will compress the natural gas to about 65 bar, and the unit for Puitatu will compress it to about 55 bar.

Doosan digest

Doosan Skoda Power has a contract to supply GT11NM new GT rotors, repairs and services for a CCPP for Midland Cogeneration. Each rotor consists of several forgings welded together that weigh over 27 tons and measure 6.5 meters. The new rotors must be compatible with the existing turbines, achieving tolerances within 0.05 mm during the production process.

Doosan Skoda Power has signed a contract with Lansing Board of Water & Light (BWL) to supply an ST generator for a new plant in Lansing, MI. The Doosan DST-S10 (80 MW) will be installed in a CCPP with a total output of 250 M. It is scheduled for commercial operation in spring 2021.

Doosan Skoda Power conducting 3D scanning of rotor cross-sections

Ethos contract

EthosEnergy has been awarded a contract by Bizkaia Energia for the installation of its Ecomax control technology on two GE Frame 9 GTs. The contract is for installation and commissioning of the Ecomax auto-tuning technology on the Frame 9 turbines located at the Amorebieta CCPP in Bilbao, Spain.

Ecomax is a stand-alone automatic combustion optimization system which manages the dynamics of thermal performance. It eliminates the need for manual tuning, optimizing the gas turbine combustor systems in near real-time while controlling emissions and managing dynamics within the framework of operator-set parameters.

Cloud visualization

Aveva has updated its Monitoring, Control and Information Management portfolio, delivering cloud integration, visualization tools, and analytics. These capabilities are delivered in InTouch HMI, InTouch Edge HMI, System Platform, Historian and Aveva Insight.

This enhanced cloud offering is an integrated experience across engineering design data, manufacturing execution management, predictive maintenance, and more. Abu Dhabi National Oil Company (ADNOC) has deployed these tools to monitor the performance of assets and operations in oil and gas development and production, processing, petroleum and chemical products, transportation and distribution.

Turboden order

Turboden has secured a contract in Taiwan for an Organic Rankine Cycle (ORC) heat recovery plant. The new ORC plant will recover saturated steam at low pressure from biomass fuel to produce 10 MW of electricity.

MHPS digest

Mitsubishi Hitachi Power Systems (MHPS) has begun trial operation of a CCPP for the Jawa-2 Project of Indonesia's state-owned electricity provider. Situated at the Tanjung Priok Power Plant on Java Island, the natural gas-fired power generation facilities should start up in May 2019.

Jawa-2 will provide 880 MW. MHPS is providing EPC (engineering, procurement and construction) in partnership with Mitsubishi Corp. and local construction and engineering firm Wasa Mitra Engineering. MHPS is supplying two M701F GTs, two exhaust heat recovery boilers, one ST and auxiliary equipment.

In addition to Jawa-2, MHPS and Mitsubishi have jointly received an order for EPC on a 500 MW natural gas-fired CCPP under construction by PLN at Muara Karang near Jakarta. Installation of the power generation equipment, including an M701F GT, is proceeding with startup scheduled for December 2019.

Entergy Texas has selected MHPS to power its 993 MW Montgomery County Power Station (MCPS) near Willis, TX. The plant is expected to be operational in 2021.The plant will feature emissions control technology. The two turbines to be installed at the Montgomery County Power Station are air-cooled versions of the MHPS G-Series.

MHPS has been selected by Danskammer Energy to supply the M501JAC GT for the repowering of the Danskammer Energy Facility, located in Newburgh, NY. Located at the existing Danskammer site, the new CCPP is expected to generate 535 MW of baseload capacity. Plans call for the new plant to begin commercial operation in 2023.

MHPS received an order to supply an M701S(DA)X GT, ST, and power generator for Chinese steelmaker Maanshan Iron & Steel. The equipment is for a blast furnace gas (BFG)-fired CCPP with a 180 MW output. Operations are scheduled at the end of 2020.

Boiler contracts

Pacific Combustion Engineering, a division of Nationwide Boiler, has been awarded two contracts to replace aging boilers and related equipment at Veterans Administration (VA) hospitals in the Pacific Northwest. The company worked with both mechanical contractors, as well as the equipment manufacturers, to provide a custom-engineered solution that complies with the specifications of each project.

The first contract includes 3 × 250 hp Mohican model, 4-pass wetback, low-pressure Superior firetube boilers, each equipped with a Webster dual fuel burner. The second contract includes 3 × 200 hp Wichita model, 2-pass wetback, high-pressure Superior firetube boilers, also each equipped with a Webster dual fuel burner.

Each burner has been designed to include flue gas recirculation (FGR) for low NOx operation, as well as NFPA 85-compliant fuel trains and FM-approved components. Various boiler auxiliaries will be supplied to support the projects.

Indian commissioning

Bharat Heavy Electricals Limited (BHEL) has commissioned an 800 MW thermal unit in India. The 800 MW set has been commissioned at Kothagudem Thermal Power Station of Telangana State Power Generation Corp. BHEL has executed this EPC project, which includes STs, generators, a boiler and associated auxiliaries, electricals, besides controls & instrumentation, electrostatic precipitators, and Balance of Plant (BOP) packages.

Boiler order

Nationwide Boiler provided two large package watertube boilers to a pulp and paper facility in the Pacific Northwest. Each boiler traveled nearly 1,000 miles to be delivered and installed in seven days.

The order consists of two 70,000 lb/hr trailer-mounted watertube boilers.

Elliott digest

Elliott Group has appointed Michael Lordi as CEO, succeeding outgoing CEO, Yasuyuki Uruma, who has retired after 47 years with Elliott Group and Elliott's parent company, Ebara Corporation. Lordi joined Elliott in 1987 as Sales and Marketing Manager for Elliott's tube tool business in Dayton, Ohio.

Mike Lordi, Elliott CEO

Since then he has held increasingly responsible roles covering every aspect of Elliott's business, most recently as Vice President of Industrial Products (2008–2011), Vice President of Global Service (2011–2016), and Chief Operating Officer (2016–2019).

"Going forward, we will continue to strengthen the Elliott brand by leveraging the close partnership between our U.S. and Japanese operations, investing in our people and facilities, and sharpening the focus on strategy and execution," said Lordi.

Elliott Group has opened a new manufacturing facility in Bengaluru, India. The factory shares the same campus as the company's existing service center in the Bidadi Industrial Area. Fully staffed and equipped to design, manufacture and test Elliott YR STs, the facility also houses engineering, sales and service offices, as well as a training center.

Egyptian plant

Zarou Group is slated to manage and operate a power plant in Egypt built by Siemens (Zarou is fully owned by Blackstone Group). In 2018, all three 4.8 GW CCPPs built by Siemens started operation in the New Administrative Capital (NAC), Beni Suef and Burullus.

Each power plant has four generation units, each with two H-class GTs, one ST, and two HRSGs. Each turbine has a capacity of 400 MW.

Turboexpander

L.A. Turbine (LAT) has completed the design, manufacture and shipment of an L2500 turboexpander-compressor for cryogenic processing with a flow rate of 60MMSCFD to be installed in a North Dakota plant. Since 2007, LAT has designed, built and shipped 150 turboexpanders and commissioned 100+ LAT turboexpanders around the globe. ■

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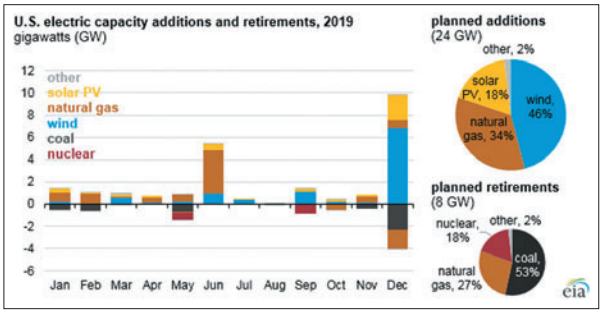
Power plant construction



Cheap and abundant natural gas, reduced production costs, and improved technology continue to give natural gas-fired power plants and renewable energy resources a competitive advantage over traditional coal and nuclear generation.

This is according to the 2019 US Gas Power Plants Engineering & Construction Trends and Outlook report. As nuclear-fired plants retire, and coal-fired units are shuttered, gas and renewables are making up an increasingly larger piece of the pie.

The U.S. Energy Information Administration (EIA) expects the share of U.S. total utility-scale electricity generation from natural gas-fired power plants to rise from 35% in 2018 to 36% in 2019 and to 37% in 2020.

Meanwhile, the EIA forecasts that the electricity generation share from coal will average 26% in 2019 and 24% in 2020, down from 28% in 2018. The nuclear share of generation was 19% in 2018 and EIA forecasts that it will stay near that level in 2019 and 2020.

The generation share of hydropower is forecast to average slightly less than 7% of total generation in 2019 and 2020, the same as 2018. Wind, solar, and other non-hydropower renewables together provided about 10% of electricity generation in 2018. The EIA expects them to provide 11% in 2019 and 13% in 2019.

Gas and renewables comprise most incremental new capacity in the U.S. and North America. The EIA projects that by 2025 natural gas will comprise about 25% of the power sector, and by 2050, 39%.

The discovery of shale gas and fracking has altered the previous $8–12/MMBtu price of long-term natural gas fuel supply contracts on the U.S. down to the $3–4/MMBtu range, making the fuel a cost-effective resource for power. Natural gas is becoming a prime fuel choice for new power generation and is now ahead of coal for the highest percentage of U.S. capacity.

The greatest opportunities for natural gas power development in the U.S. are in the Mid-Atlantic region. Owners can take advantage of inexpensive and abundant Marcellus shale gas, as well as gas from Texas and the Louisiana Gulf.

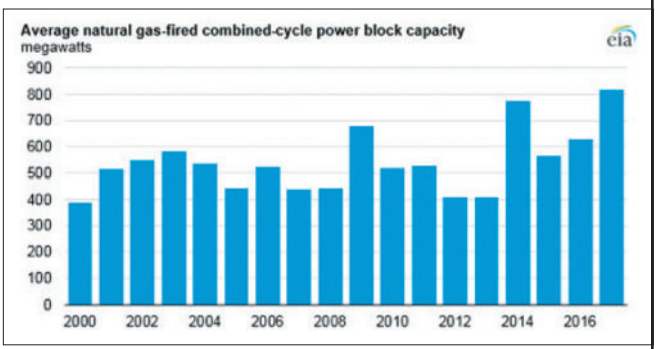
According to the EIA, 23.7 GW of new capacity additions and 8.3 GW of capacity retirements are expected for the U.S. electric power sector in 2019. The additions consist primarily of wind (46%), natural gas (34%), and solar photovoltaics (18%), with the remaining 2% consisting of other renewables and battery storage capacity.

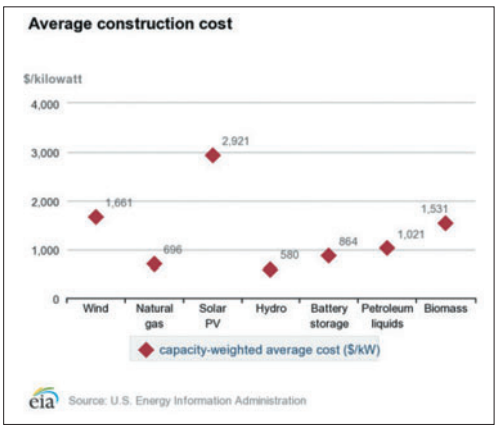
Planned natural gas capacity additions are primarily in the form of CCPPs (6.1 GW) and peaking plants (1.4 GW). Most of the natural gas capacity is scheduled to be online by June 2019 in preparation for high summer demand. Of the planned natural gas capacity additions, 60% will occur in Pennsylvania, Florida and Louisiana.

Construction costs for natural gas-fueled power plants are around $696 per kW capacity. Weighted average costs are one of the lowest, just behind hydro power. This is less than solar at $2,921 per kW, wind at $1,661 per kW and biomass at $1,531 per kW, according to the EIA.

Wind is a large part of the 2019 and 2020 project spend as developers look to use tax credits before expiration. While incentives still exist for wind and solar in the U.S., the subsidies are winding down.

Production tax credits for wind will expire at the end of 2019, and the solar tax credit, which is now 30%, will decrease to 10% in 2020. With 2020 being an election year, many believe it is unlikely that legislation will be developed to extend or create new renewable energy tax credits before the wind incentive expires. As the tax credits fade, this could open opportunity for more natural gas plants to be built.





Power blocks in natural gas-fired combined-cycle plants get bigger

Since 2014, the average size of a natural gas-fired CCPP has increased significantly, according analysis by the EIA. The average power block installed between 2002 and 2014 was about 500 MW. Capacity reached an average of 820 MW in 2017.

The most common configuration involves two GTs supporting one ST. The capacity-weighted average heat rate of power blocks less than 500 MW is 6% higher (or less efficient) than that of power blocks larger than 1,000 MW.

Larger blocks generally have lower per-unit capital costs, making them more attractive investments. However smaller blocks, which inherently have lower minimum loads, are commonly associated with greater flexibility because they can operate through low demand periods without having to shut down. ■

TURBOMACHINERY FOR FPSO VESSELS

AMIN ALMASI

A floating production, storage and offloading (FPSO) vessel is used by the offshore oil & gas industry for the processing of hydrocarbons. It receives hydrocarbons from subsea or nearby platforms, processes them, and stores them until they can be offloaded to a tanker.

FPSOs are preferred in frontier offshore regions as they are easy to move and operate, and do not require a local pipeline infrastructure to export oil. In some cases, they are converted oil tankers, and in others they are purpose-built. FPSO vessels are effective in remote or deepwater locations where seabed pipelines are not cost effective.

The first FPSO was built at the end of the 1970s. Today, over 200 such vessels are deployed worldwide. FPSOs have been historically used in areas such as the North Sea, Brazil, Asia, Australia, the Pacific, the Mediterranean Sea and West Africa.

Modular design

FPSO processing equipment is similar to what would be found on a production platform. Usually built in modules, this includes water separation, gas treatment, oil processing, water injection and gas compression. Many different types of pumps and turbomachinery are needed.

Layout of topside facilities is usually driven by the sequential placement of processing systems coupled with safety compliance policies. No single layout works for all configurations. There are, however, common rules influencing design.

Each major system is typically packaged, skid-mounted and installed as a one-piece module. Modularized components are particularly important for turbomachinery.

Safety is paramount. Modules are placed away from living quarters and control buildings. Only benign or non-hazardous equipment is located near commonly occupied safe areas. This policy drives the overall configuration of an FPSO.

More hazardous systems like gas compressors, production modules, and vents or flares usually are situated at one end of the vessel. These modules are placed in a sequential order following a decreasing level of risk; low risk units might be on the side of accommodations, but still a proper distance away. High-risk facilities are always on the side of FPSO farthest away from personnel areas.

Motion-sensitive equipment and machinery is generally installed near the vessel's center. High-speed rotating equipment, such as compressors and generators is usually aligned along the length of an FPSO. Large reciprocating compressors are often placed in cylinders transverse to the FPSO, using bulkheads to resist unbalanced forces and moments.

Fabricated for reliability and availability, FPSO turbomachinery should be compact, lightweight and designed with safety in mind.

When crude oil properties necessitate, additional treating equipment is incorporated into an FPSO. Crude oil heating, desalting, sand or sulfur removal, and heavy oil dilution are such additions. All require additional sets of pumps and specialized turbomachinery.

Some compressed gas may be used for lift gas or re-injection gas to enhance oil production. Such an option, though, usually requires the addition of large turbocompressor elements. When water injection pumps are needed to maintain reservoir pressure or dispose of produced water, dedicated pump sets can be added. When seawater is injected into the oil reservoir, powerful seawater pump sets are included along with additional systems to treat and deoxygenate seawater.

FPSO machinery should be fabricated for reliability and availability. It should be compact, lightweight, and designed with safety in mind. It should also be properly monitored to prevent unnecessary downtime.

Offshore gas compressors are used for various tasks including reservoir management, production enhancement, and the transmission or processing of gas. A variety of different refrigeration compressors have been used in FPSOs, such as those needed for Liquefied Petroleum Gas (LPG) refrigeration.

A commonly-used package is a centrifugal compressor for a propane and refrigeration unit (a two-stage cooling cycle using a closed loop of propane as the refrigerant). The compressors vary from conventional to integrally geared.

The propane refrigeration unit is often installed in an enclosed deckhouse located topside. A re-liquefaction unit is usually required for an LPG FPSO. It is usually provided to separately handle the boil-off gas from the propane and butane storage tanks.

Onshore tankers

This is often different from the models commonly deployed on onshore LPG tankers. As a rough indication, compressors in a medium-sized FPSO might consume anywhere from 5 to 20 MW of power.

Since an FPSO can be moved from one offshore field to another, operating conditions can shift markedly. Therefore, operational flexibility is an important requirement. This can include varying gas flows, different gas compositions, and a wide range of pressure ratios.

Compressors are generally run constantly due to project economics. This presents a challenge for compressors in harsh offshore environments. (*Turbomachinery International* July/August 2017 p. 30). Adopting a condition-based maintenance strategy can minimize downtime. ■

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.

SURVIVING DIGITALIZATION

SUCCESS COMES WITH CYBERSECURITY

BY DREW ROBB

"Go digital, young man!" is the mantra preached by OEMs, service providers and controls experts. But the journey toward digitalization requires opening up the plant and its systems to external networks.

For every potential benefit, a nasty collection of threats lurk. Hackers, criminals, nation-state infiltrators, and even kids up to mischief can use the network to gain access to critical systems.

If digitalization is inevitable, then so is cybersecurity. Yet many facilities are unprepared. A study by analyst firm Gartner found security and privacy to be top concerns when it comes to the adoption of digitalization technologies, such as the Internet of Things (IoT). Yet 84% of organizations are insufficiently prepared.

Companies, such as OSIsoft, Dragos, GE, XMPLR Energy, ABB, KnowBe4, Mitsubishi Hitachi Power Systems, CCC, Amazon Web Services, and Aperio, are putting in place best practices and systems to address cybersecurity.

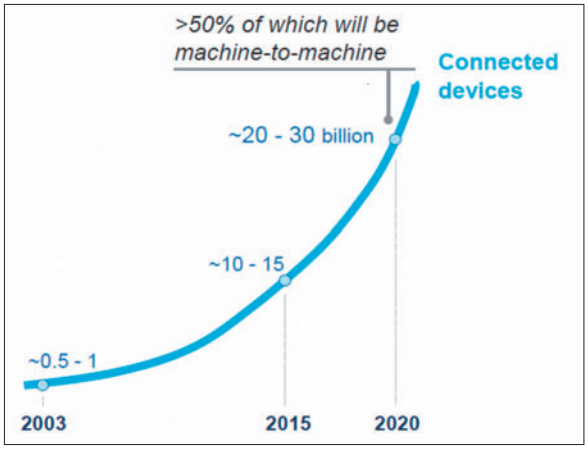
Experts concur that the first step is having a cybersecurity plan. And that is where many users stray. They either do not have a plan, or the plan only deals with threats when they occur.

The right plan includes how to identify assets at risk, how to protect them, how to detect incursions, how to ensure compliance, how to recover from a breach, and how to respond.

"The power industry should be concerned about cybersecurity as it is a real risk," said Scott Affelt, President of consulting firm XMPLR Energy. "At the same time, they can't put the organization on hold while they wait to get secure."

Scott Affelt

He noted that the number of connected devices will double over the next few years, exceeding 20 billion by 2020. More than half of those connections will be machine-to-machine, flowing automatically across business systems. This opens a wide highway to hackers into those systems.



By 2020, more than 20 million connected devices will be in existence.

He advised the industry to introduce cybersecurity into management processes, and to make a comprehensive plan. The elements required are:

- Making an inventory of all assets to identify those at risk
- Setting up a strength-in-depth strategy composed of many layers of protection
- Detecting incursions that find a way through those defenses
- Complying with regulations, such as North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP)
- Determining how to recover when a breach occurs
- Unearthing any and all points of a breach
- Hardening the organization against further incursions.

A new report by Markets and Markets found that the CIP market will grow from $110 billion in 2017 to $153 billion by 2022. The network security segment is projected to grow the most during that forecast period.

The various network security solutions include identity and access management, risk and compliance management, encryption, firewalls, antivirus/antimalware, intrusion detection systems, and intrusion prevention systems.

Network security solutions safeguard the critical systems network from malware, ransomware, viruses, worms and other attacks. The physical security segment, though, is expected to have the largest market share and dominate the CIP market from 2017 to 2022, due to growing instances of physical attacks and natural disasters on industrial plants, oil fields and ports.

"It is vital to prioritize assets and all related risks," said Affelt. "Focus on key assets, engage all employees and educate them so they help you in watching out for threats."

Some 91% of security incidents come in via what is known as phishing. This is where hackers send out malicious emails posing as legitimate communications. They may pretend to be from suppliers, manufacturers, people within the organization, clients and financial firms. The goal is to get the person to click on a link or open an attachment. And presto, the bad guys are inside.

Being asset-centric, the good news is that power producers and utilities are less at risk than other industries, such as financial services. But initiatives, such as smart metering, remote monitoring, IoT, and the cloud are changing that.

"You can't eliminate risk, you can only manage it," said Affelt. "Being compliant does not equal being secure. It requires tight collaboration between IT and operational technology (OT) staff."

Roger Grimes, Defense Evangelist at cybersecurity training firm KnowBe4, called attention to recent revelations of successful Russian-sponsored attacks against power grids in various countries, and a growing real-world threat by North Korea and other hostile countries. This served to make energy companies more aware of the threats they face.

"For over two decades, management at energy companies in the U.S. and elsewhere thought they were doing okay on computer security," said Grimes. "They knew they had lots of weaknesses and vulnerabilities, but a lack of big attacks gave a false sense of security."

He noted that 90% or all successful data breaches are accomplished by social engineering. This involves phishing emails that take the guise of benign messages

from banks, suppliers, or other trusted sources. "Energy companies should focus on preventing social engineering and phishing," said Grimes.

He recommends security awareness training. KnowBe4 offers systems to detect and prevent phishing, as well as training users to greatly lower the incidence of breaches. This involves grading user susceptibility to phishing followed by education to increase awareness.

Cyber plan

"A good place to start is to gain executive support backed by funding to manage cybersecurity," said Dee Kimata, Cybersecurity and Collaboration Operations Center Product manager at ABB's Power Generation & Water business. "There must be an organizational commitment to define baseline security requirements, and then to routinely measure yourself against those baselines."

Some of the actions of the plan require collaboration, assessment and the establishment of procedures. Others can be set up automatically. ABB uses a lifecycle support model for industrial cyber security: identify, protect, detect, respond.

On the protect step, for example, you can automate patch management, backup and virus protection. Kimata also recommended a defense-in-depth approach consisting of multiple complementary layers. This includes tools, such as firewalls, network anomaly detection, phishing protection, security awareness training and behavioral analytics.

She added that compliance mandates, such as NERC CIP often serve as the driver for organizations to begin facing the necessities of cybersecurity.

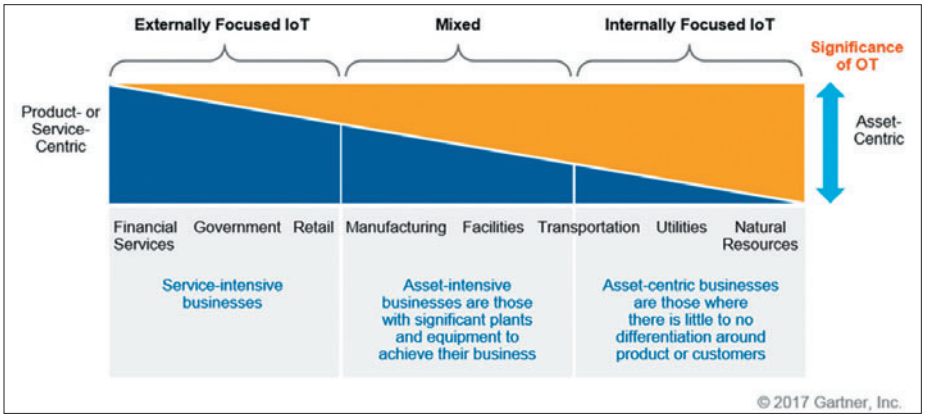
"The key to management of an incident is how effectively an organization can recover and with minimal impact," said Kimata. "Processes must be in place to respond adequately to incidents."

OEMs are responding, as well. MHPS has developed its Tomoni control system. It incorporates a great many cybersecurity protections, as well as the use of handhelds, voice recognition and artificial intelligence (AI). You can ask the system how the plant is and receive a verbal response.

"In the past, you discovered an intrusion and dealt with the aftermath," said Paul Browning, CEO of MHPS. "Nowadays, AI can recognize anomalous behavior and shut off access to prevent intrusions before they occur."

Cybersecurity partnerships

There is currently a lack of visibility into cyber threats related to control systems. Several power generation and control specialists are partnering with IT firms to bring greater cybersecurity smarts into the industry. Dragos, the developers of the Dragos Industrial Controls Systems (ICS) threat detection and response platform, is collaborating with GE to help owners and operators more effectively detect and respond to industrial cyber security threats.



Asset-centric industries such as power generation and oil & gas have a lower risk profile than other industries when it comes to cybersecurity. However, risk exists and must be managed

Benefits are said to be broader threat detection and response capabilities, greater insight into ongoing threats, cybersecurity training and practical guidance for industrial engineers.

Similarly, cloud vendor Amazon Web Services (AWS) and OSIsoft are working together. OSIsoft's PI System transforms operational data streams from sensors, devices and industrial processes into real-time insights to save money, increase productivity or create connected products and services. Over 1,000 utilities, 90% of the world's largest oil and gas companies and 65% of the Fortune 500 industrial companies, rely on the PI System in their operations.

Quick Starts for AWS lets you stand an OSIsoft PI System on AWS. In addition, PI Integrator for Business Analytics delivers PI System data to AWS to reduce time and cost of bringing operational and IoT data to AWS for sharing or analytics.

Enhanced connectivity and data sharing can also accelerate digital transformation and shrink the OT-IT gap. This is said to reduce the time consumed by data preparation in analytics projects by over 90%.

AWS Quick Starts for the PI System consists of templates, reference architectures and other technologies for quickly managing a fully functioning PI System in the Amazon cloud. It can be used to monitor remote or isolated assets and integrate analytics into operations, such as running day-ahead pricing scenarios at oil and gas operations or conducting plant-to-plant comparisons.

Attacks have occurred. An incident a few years ago tricked operators at Iranian nuclear plant into believing their systems were normal when a centrifuge was breaking down, said Michael Kanellos, IoT Analyst at OSIsoft. It knocked out 20% of Iran's centrifuges. In 2015, Ukraine's grid operator got hit with a similar virus. And last year, Saudi Arabia's oil industry was hit with a related virus.

Hackers are coming up with tools that create artificial data that manipulate equipment (turn it off or on, for example) or manipulate data coming off a system to prompt an engineer or other party to take an action that is not in their interest, i.e., remote systems might be overheating but everything looks normal.

Suspicious behavior

"Malware can present power plant operators with wrong data," said Kanellos. "But by combining data from OSIsoft and Dragos systems, it is possible to detect patterns that indicate suspicious behavior."

Facilities worried about their systems being accessible over the network can set up what is known as a one-way diode, said Kanellos. Data can be sent from the facility to the cloud, but it is impossible for anything from the cloud to come back into the enterprise.

The diode converts digital information from the plant into optical signals before sending it to the cloud. There is no equivalent optical converter to send data from the cloud back to the plant. A diode can cost $30,000 or less, said Kanellos.

"This technology, currently used in nuclear facilities, oil refineries and other highly sensitive sites, is coming to power plants," said Kanellos. "Waterfall, a diode company, is working with CNA Hardy insurance to give a premium discount to those who implement a data diode. We also recommend data encryption."

OSIsoft is working with Lawrence Berkeley Lab on research that uses physics to compare network data and find discrep-

Continued on page 20

How the Bad Guys Attack

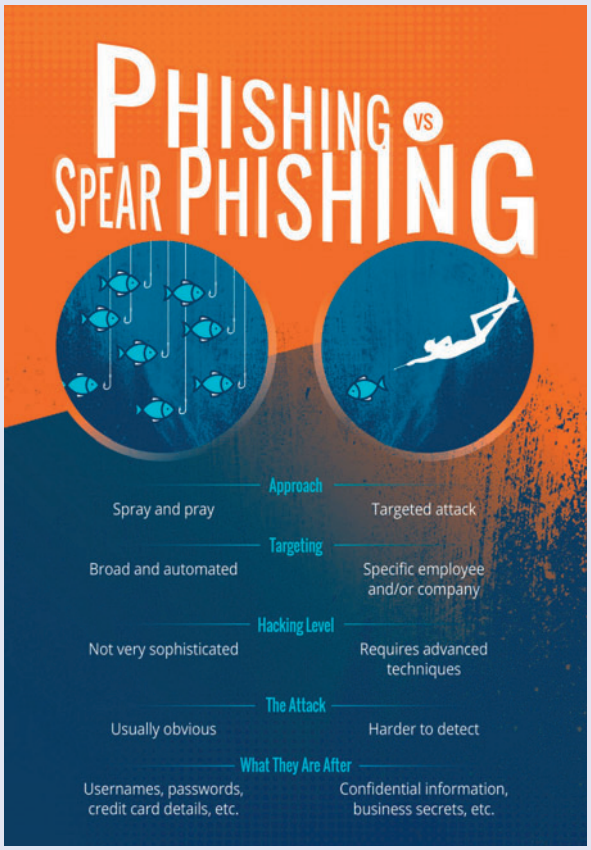
It is surprisingly easy to find email addresses. There are even data exchanges that cybercriminals use to buy and sell email lists, passwords, and other security credentials. In the past, they were used to send scam emails to large numbers of people.

Promises of millions from Nigerian bank accounts, lottery winnings, and other schemes tricked more than a few out of their savings.

These days, organizations are regarded as juicer targets. Hackers use phishing or spear phishing to compromise security. Phishing emails are fairly easy to spot, although they still achieve success. Spear phishing is the preferred avenue of attack into corporations.

It is really the same as phishing only its highly targeted rather than "spray and pray." The cybercriminals go after a top exec, or someone in finance with access to funds or corporate secrets.

The goal is to dupe the person into transferring money, giving out bank details, or granting access to intellectual property files. The U.S. FBI has recently issued alerts to top management organizations about this threat as hundreds of millions have been stolen in this way.



Courtesy of KnowBe4

KnowBe4 recommends training of employees on how to spot phishing emails. Before training, the company sends out a simulated phishing attack to determine open rates. After training, it continues to send out these emails and reeducate employees until the open rate is considerably lowered. This type of approach is one industrial companies should consider as a way to harden their security perimeter.

ancies. It is also collaborating with Aperio, which takes a slightly different tack.

It analyzes reams of historical data and looks for anomalies. It does not care about the value of the data as much as unusual variations. If something rises 10° rapidly, for instance, it might be flagged as synthetic. Likewise, he said, Dragos offers similar services on attacks from the inside.

Compressor Controls Corp. (CCC) has released an upgrade to its turbomachinery controls platform. Known as Total Train Comprehensive Release version 14.1, it is focused on improving cybersecurity defense around turbomachinery. The upgrade process is done without loss of data or process disruptions. Its familiar Human Machine Interfaces (HMIs) will operate without change.

"The new features strengthen cybersecurity awareness and response capabilities," said Rich Hall, Vice President of Product Management and Marketing at CCC. "We've implemented a cybersecurity program that complements good industry practices, such as separation of turbomachinery controls and protection systems to provide improved security."

Courtesy of KnowBe4

Many plants balk at the high cost of security systems. What is not realized is that it is far more expensive to suffer an attack. According to 2018 research conducted by the Ponemon Institute, the global average cost of a data breach is up 6.4% over the previous year to $3.86 million. Making security investments can help ensure that anything that resides on a network is safe.

Security is one of those investments that is never finished. Some think they can buy some software and be done with it. But that is only the beginning. It takes trained personnel, keeping systems up to date, and vigilance throughout the facility.

With modern plants running thousands of devices connected through the IoT, the successful convergence of OT and IT has become a business imperative on the executive-management agenda.

Voith and Kudelski are partnering to help integrate and secure systems across both IT and OT. They are offering advisory services to provide the framework for putting the right safeguards in place using a managed security services model. This will combine expert analysis, threat monitoring, intelligence sharing, and rapid detection and response to threats to protect the plant around the clock. Kudelski delivers contextual threat intelligence and predictive security, while Voith provides OT expertise and tech support on the ground at the customer site.

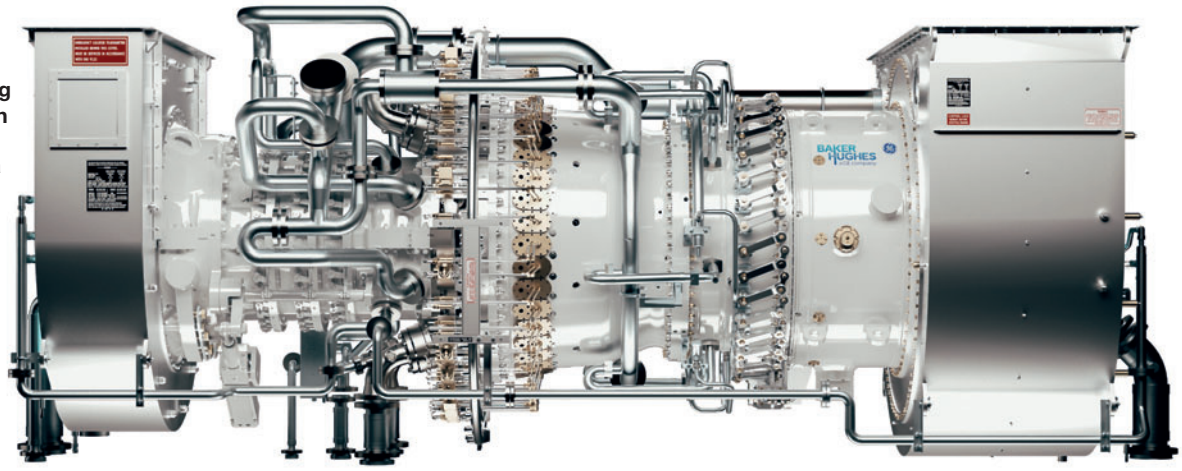
Digital security

Digital transformation is the buzzword of the moment. Many companies are engaged in strategies to more closely integrate various data pools within the organization.

Analyst firm International Data Corp. is forecasting the global spend on digital transformation will reach nearly $2 trillion in 2022. But while digitalization has a host of benefits, it exposes energy producers, utilities, OEMs and oil & gas companies to far more potential risk.

Tina Stewart, Vice President of Strategy at Thales eSecurity said basic security measures such as encryption are in use by fewer than 30% of organizations deploying cloud, big data, and IoT applications. Further, those most aggressively pursuing a digital strategy run the highest risk of a data breach.

"Organizations need to take a fresh look at how they implement data security and encryption in support of their transition to the cloud and meeting regulatory and compliance mandates," said Stewart. ■



The BHGE NovaLT gas turbine is being modified to run on 100% hydrogen for a project in Australia

THE HYDROGEN TURBINE

RECONFIGURING BHGE'S NOVALT GAS TURBINE FOR 100% HYDROGEN DUTY

BY DREW ROBB

Gas turbines (GTs) running on 100% hydrogen have been a long-term dream (*Turbomachinery International* Nov/Dec 2018). The concept has gained momentum in tandem with the trend toward carbon neutrality. Now that coal-powered facilities are being legislated out of existence in many countries, attention has turned to finding ways to transition natural gas-fired turbines over to alternate fuels.

Baker Hughes GE (BHGE) is working to bring the 100% hydrogen dream to reality. It has signed an agreement with Australian hydrogen infrastructure developer H2U to modify a NovaLT GT to run solely on hydrogen at a green hydrogen power facility in Port Lincoln, Australia.

"NovaLT generators were chosen because they could operate on 100% hydrogen at all times," said H2U CEO Attilio Pigneri. "The annular combustor design and dual-shaft configuration will enable the unit to deliver black-start capability while still operating on 100% hydrogen."

H2U is building a 30 MW water electrolysis plant, as well as a facility for sustainable ammonia production near Port Lincoln. The Port Lincoln Project includes a 15 MW electrolyzer plant, distributed ammonia production facility, 10 MW hydrogen-fired GT, and a 5 MW hydrogen fuel cell. This will make it one of the first commercial plants to produce carbon dioxide-free green ammonia that can be used as an industrial fertilizer for farmers and aquaculture operators.

The Port Lincoln plant is situated beside a facility that produces ammonia from hydrogen via electrolysis. Some of that hydrogen can be deployed for peaking power when there are favorable market conditions, or as standby power in the event of a grid outage. The plant can either use grid supply, on-site solar power or hydrogen-powered electricity as required.

With no natural gas pipeline infrastructure nearby, hydrogen-powered turbines were the best option. Up to two BHGE NovaLT16 GTs will operate at the facility, which will be able to produce up to 32 MW.

"The NovaLT 16's annular combustor is needed to startup and progressively fire up hydrogen generation without misfires," said Pigneri. "As it is an aeroderivative gas turbine, it can withstand high temperatures, is easy to maintain, and can ramp rapidly."

BHGE is building on its experience with hydrogen-fueled gas turbine combustion system developed for the Fusina plant in Venice (Italy) to ready the NovaLT16 for the H2U project. The combustion chamber will be modified to run on 100% hydrogen.

BHGE plans to tune the design with a full-scale annular rig test at the Sesta Laboratory in Italy, as well as with single-capacity tests in its Florence facilities. Final validation of the modified combustor will be done in the prototype engine.

In addition, control software will be adjusted and minor improvements will be made to the package. NOx emissions of the hydrogen-fired turbine will be managed within acceptable limits.

"The capability to ramp up within minutes is critical as the Australian grid operates at five-minute intervals," said Luca Maria Rossi Chief Technology Officer of Turbomachinery Process & Solutions at BHGE. "The NovaLT16 turbines will support critical loads within the Port Lincoln facility, while also contributing generation to the grid during periods of low wind or solar output."

Construction at Power Lincoln will begin in 2020 with commissioning and commercial operation slated for either late 2020 or early 2021. ■

BHGE and H2U sign deal to deploy the NovaLT gas turbine at Australian plant. From left to right: Luca Maria Rossi and Rod Christie, BHGE; Attilio Pigneri and Tristram Travers, H2U

BHGE's Simonelli announces a company net-zero goal for carbon by 2050

GET READY FOR A LOW-CARBON FUTURE

BHGE COMMITS TO ENVIRONMENTAL RESPONSIBILITY FOR THE OIL & GAS SECTOR

BY DREW ROBB

The 2019 Baker Hughes GE (BHGE) Annual Meeting in Florence, Italy sounded more like a Green Party rally than a mainstream oil & gas event. Speaker after speaker stressed environmental responsibility and decarbonization.

Giants such as Norway's Statoil (now known as Equinor), BP, Shell, BHGE, QatarGas, Saudi Aramco, Tellurian, Anadarko, Petronas, Jera, Novatek, Venture Global, SIA Energy, Aker BP, Eni, and Great Western Oil & Gas, as well as oil & gas ministers from around the world spoke passionately about lowering emissions, doing their part to meet targets from the Paris Accord on climate change, and harnessing digitalization to prepare for a future shared between their industry and renewable energy.

Notable, too, was a subtle shift from oil toward gas. With its lower emissions and less-tarnished image on the environmental front, natural gas is being voiced by industry executives as a production priority ahead of oil.

Industry groups are singing a similar refrain. EUTurbines, an association of European gas and steam turbine manufacturers (composed of Ansaldo Energia, Doosan Škoda Power, GE Power, MAN Energy Solutions, Mitsubishi Hitachi Power Systems, Siemens and Solar Turbines) is advocating what it calls the transition to a decarbonized energy mix in line with the EU's 2050 goal of a climate neutral economy.

"The gas turbine (GT) sector should offer solutions which will convert a large variety of renewable energy fuels to progressively replace natural gas," said Ralf Wezel, Secretary General of EUTurbines. "By providing the technologies that will drive the transition to fast-adapting, cost-efficient and renewable gas-based generation, we ensure that investments in GTs will not become stranded assets."

BHGE commits

"Oil and gas will continue to be an important part of the global energy mix," said Lorenzo Simonelli, chairman and CEO of BHGE. "We are committed to reducing our CO_2 equivalent emissions 50% by 2030 and achieving net-zero CO_2 equivalent emissions by 2050."

BHGE has already been making progress along this path. It has achieved a 26% reduction in emissions since 2012 through technology improvements and operational efficiencies. A 3% reduction year over year is required to meet the 2030 goal.

3D printing and artificial intelligence are ways to reduce cost, lower emissions,

lower transportation needs and eliminate waste, said Simonelli.

"Annually, 10% of CO_2 emissions come from oil and gas; we have to do something about it," said Simonelli. "Natural gas is the fuel for a low carbon future."

To further industry and customer efforts to reduce carbon emissions, BHGE's Gaffney, Cline and Associates has launched a Carbon Management Practice. This is the first oil and gas consultancy to offer quantitative assessment of carbon intensity, evaluation of carbon solutions, and the accreditation of emission reductions.

This new practice helps governments, energy companies, and the financial community understand and solve energy transition issues related to oil and gas resources, assets and investments.

BHGE backed these announcements with technology releases aimed at supporting operators' efforts to reduce their carbon footprint.

Lumen technology from BHGE consists of a drone and ground units to monitor methane levels

Monitoring and inspections

BHGE's Lumen is a suite of methane monitoring and inspection solutions capable of streaming live data from sensors to a cloud-based software dashboard. The platform consists of a ground-based solar-powered wireless sensor network, and a drone system for over-air monitoring. This delivers closer control of methane emission rates and concentration levels (PPM).

"Methane leak detection is one of the most pressing needs in the oil and gas industry today," said Diarmaid Mulholland, CEO of BHGE's Measurement & Sensing business. "Using sensors and industrial software, Lumen helps operators to protect the environment by detecting harmful methane leaks. Using data analysis, this technology helps identify and reduce emissions while also increasing safety for operators."

Lumen's solar-powered sensor system known as Lumen Terrain is a wireless system that creates a digital mesh network around a facility, outdoors and indoors. Lumen Sky is the airborne portion which can provide high-definition aerial video streaming for data visualization. Data such

as the location of a leak is available in real-time via a computer or smartphone.

Meanwhile, BHGE has signed an agreement with Australian hydrogen infrastructure developer H2U to configure the NovaLT GT to operate on 100% hydrogen for the Port Lincoln Project, a green hydrogen power plant facility in South Australia (p. 21).

Further announcements at the annual meeting also relate to lower-carbon technology:

- Modular gas processing at the Nassiriya and Al Gharraf oilfields in Iraq will recover 200 million standard cubic feet per day of flare gas. The recovered gas will be processed into dry gas, liquefied petroleum gas and condensate, and will support domestic generation as well as exports
- The offshore Integrated Compressor Line operates with zero emissions. It is driven by a high-speed electric motor in a single sealed casing and its rotor is levitated by active magnetic bearings (AMBs)
- Flare.IQ provides accurate, near-continuous control of downstream flare performance by optimizing combustion efficiency, allowing operators to reduce flaring-related emissions.

Ministerial view

Each year, top brass from oil & gas giants as well as government energy ministries gather in Florence. Many are featured on panels or deliver keynotes.

Tarek El-Molla, Egypt's Minister of Petroleum and Mineral Resources forwarded the message of environmental stewardship. His country has recently transitioned from being an LNG importer to an exporter of natural gas.

"We have a lot of gas stranded in the Eastern Mediterranean and need to cooperate with others in the region to capitalize on it," he said. "We are investing more in natural gas and LNG rather than oil."

Eldar Saetre

However, he warned about too much of a pendulum swing. A big drop in investment in oil could lead to a potential shortage in the future.

Eldar Saetre, President and CEO of Equinor, began his keynote by saying the future would be markedly different for the energy industry. He counselled his peers to understand the drivers for change and to be prepared to be surprised. The transition in energy use is ongoing and that is disrupting the status quo, he said.

"We must grasp the growing expectations concerning our ethical behavior, social engagement and environmental responsibilities," said Saetre. "We are experiencing pressure from investors to produce oil and gas with increasingly lower emissions and add more renewable resources."

He urged the audience to educate people on the industry, listen to young people, and stay relevant to future generations. He sees digitalization as a tool that can help meet these challenges and transform the industry. Potential benefits include lower development and operating costs, faster discovery and recovery, reduced emissions and improved safety.

"Digitalization will enable increased sharing and cooperation within and along the value chain," said Saetre.

He listed key areas to address. Innovation is needed to bring oil and gas down to the lowest possible emission levels. Research must be stepped up to bring about decarbonization of energy, including the use of hydrogen as a fuel source. And alternatives must be found to coal in the short term and eventually for both oil and gas.

Mohammed Y. Al Qahtani, Senior Vice President Upstream for Saudi Aramco, provided a tangible example of the kind of gains Saetre calls for. His company cut inspection time by 90% in one of its gas plants using Artificial Intelligence (AI) and other technologies.

"A single gas plant generates many terabytes of data every day, yet we only tap into a small portion," said Qahtani. "Analytics allows you to sift through the data to extract features invisible to the human eye to aid discovery and production."

Richard Frommer, President and Chief Executive Officer, Great Western Oil & Gas, explained that oil & gas companies are now operating under the microscope. His company has reduced its emissions by over 50%.

"We have to work hard for our social license to operate," said Frommer.

Neil Gilmour, Shell's Vice President of Integrated Gas, Projects and New Energies, echoed the sentiment that an energy transition was ongoing and that operations were under greater scrutiny.

Energy Information Agency projections show natural gas use in the world increasing from 22% in 2017 to 25% by 2040. However, an alternate scenario based on broad acceptance of sustainable development policies and stringent environmental regulations could curtail growth if it became reality.

LNG growth

Liquefied Natural Gas (LNG) is one of the biggest growth areas within oil & gas. Rajnish Goswami, General Manager of LNG Marketing at Anadarko, discussed the Mozambique LNG Project.

With about 75 trillion cubic feet of recoverable natural gas discovered offshore, the country is well positioned to meet the needs of customers in the Atlantic and Asia-Pacific markets, and tap into growing demand for energy in the Middle East and the Indian sub-continent.

Anadarko and the other participants in Mozambique LNG are collaborating with the government on this 12.8-million-ton plant on the Afungi peninsula. Testing demonstrated flow rates of 90 to 100 million cubic feet per day (MMcf/d), which supports well designs of 100 to 200 MMcf/d.

As a result, Anadarko has signed multiple supply contracts. It recently inked a deal with Indonesia's Pertamina to sell 1 million mt/year of LNG from the Mozambique LNG project for 20 years. That brings the total of deals signed to seven for more than 9.5 million mt/year. Other customers include India's BPCL, China's CNOOC, Shell, UK's Centrica and Tokyo Gas.

These contracts highlight an ongoing shift in the LNG market. Hendrick Gordenker, Chairman of Jera, a major buyer of LNG, said that traditional LNG buyers in developed markets, such as EU, Korea and Taiwan, will not be major growth areas for LNG. While China grabs all the headlines as a booming market, he pointed out that there are dozens of emerging markets that should also be given attention. Each one may not compare well against China, but collectively they are likely to amount to a large slice of future LNG consumption.

Novatek's Arctic LNG 2 in Siberia is another big LNG project under development. Once operational, it will have a production capacity of almost 20 million tons. Owner Novatek is working with Italy's Saipem to build offshore platforms for Arctic LNG 2. The facility is being assembled on gravity-based platforms and production is scheduled by 2023.

Mark Gyetvay, Chief Financial Officer & Deputy Chairman of the Management Board, Novatek said the company launched train two and three last year for the Yamal LNG project.

That takes the Yamal plant to its

planned capacity of 16.5 million tons per year less than a year after the first shipment of LNG from the project. It is operated by the Yamal LNG Company, owned by Russian independent gas producer Novatek (50.1%), Total (20%), CNPC (20%) and Silk Road Fund (9.9%).

It includes an integrated gas treatment and liquefaction facility with three trains of 5.5 million tons per year capacity each, storage tanks, and port and airport infrastructure. An additional small-scale 0.9 Mtpa train is under construction with a start-up planned early 2020.

Yamal LNG's production is sold under long-term contracts in Asian and European markets. LNG will be supplied to the markets all year round through a fleet of ice-class LNG carriers that travel the Northern Sea Route to Asia through the Bering Strait in the summer.

"If we can achieve LNG cost competitiveness around the world, demand will be there," said Gyetvay. "Ice tankers for Arctic projects can halve the time to deliver LNG to Asian markets."

Michael Sabel, Co-CEO, Co-Chairman and Founder of Venture Global, a supplier of LNG, argued that it was necessary to shrink the scale of LNG liquefaction trains and re-size equipment to achieve savings of as much as 30% in project costs.

BHGE has been the recipient of LNG-based orders from these and other companies. It will supply turbomachinery equipment for the construction of the Golden Pass LNG export facility in Sabine Pass, TX. The project is expected to produce around 16 million tons per year of LNG. It is 70% owned by an affiliate of Qatar Petroleum, with ExxonMobil and ConocoPhillips affiliates owning the remaining shares.

BHGE will provide three LNG trains, including six MS7001 EA heavy-duty GTs driving 12 centrifugal compressors. The MS7001 EA is a large industrial gas turbine available in the LNG market, with 77 units in operation in 13 countries.

ExxonMobil and Qatar Petroleum plan to proceed with construction in the first quarter of 2019. The project's goal is to be the lowest cost LNG supplier on the U.S. Gulf Coast through optimized maintenance cycles.

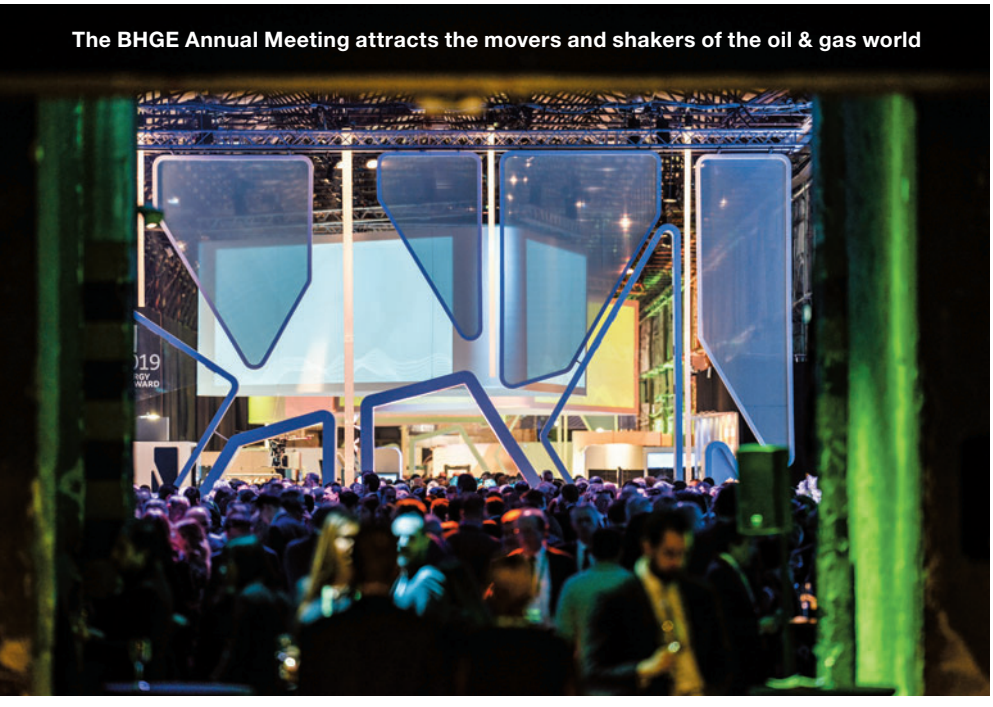
Chinese LNG

China has high demand for LNG and natural gas. Yao Li, Founder & CEO of SIA Energy, said that for the second year running, gas consumption in the nation rose by 16%. LNG imports, meantime, grew at 41% last year to 54 million tons per year.

In 2016, China's coal use was 30% of the total. A concerted effort to switch to natural gas, renewables and geothermal energy has brought down pollution. But a lot more LNG imports are required to further reduce coal consumption.

"We have to be realistic about how much gas can reach end users," said Li. "We have major infrastructure constraints, such as lack of underground storage, pipelines and transmission lines."

China has 5% of the underground gas storage capacity of the U.S., for example. This curtails the volume of LNG imports the country can accept. But despite that, China will soon overtake Japan as the largest importer of LNG in the world.



The BHGE Annual Meeting attracts the movers and shakers of the oil & gas world

Tarek Souki

Tarek Souki, Senior Vice President of LNG Marketing and Trading at Tellurian, views the expansion of LNG production as a driver of commoditization in the natural gas market. This will help to stabilize prices around the world and ease the transition from coal.

"Natural gas and renewables should be viewed as partners, not adversaries," said Souki. "We need both to effectively lower coal consumption and must work together."

He mentioned that the combined LNG storage of Japanese and Korean terminals is 697 bcf. But the largest LNG vessels can now provide 821 bcf of floating storage. Thus, as more LNG vessels are built, this will lead to further commoditization.

His company is also involved in reconfiguring the pipeline network in the U.S. to cope with the massive infusion of natural gas. The network is set up to move gas from offshore sites in the Gulf of Mexico to major markets in the Northeast. But some of the flow is now being turned to new export terminals.

"The U.S. has far more shale gas than it can consume, but we needed a huge investment to build the pipeline network to cope with 60 million tons of liquefaction capacity," said Souki.

LNG turbomachinery

The latest GT developments were summarized by Luca Maria Rossi, CTO of BHGE's Turbomachinery Processing Solutions. The company's newest aero derivative, the LM9000, is a 70 MW class GT being co-developed with GE Aviation.

The unit is currently in testing at BHGE's Massa facility in Italy. The LM9000 has been designed from the beginning with LNG in mind. Its free power turbine design will allow an LNG train to startup in a fully pressurized con-

dition without venting process gas or requiring an electric helper motor.

Its Dry Low Emissions (DLE) combustion system with flexible fuel technology reduces emissions while eliminating water needed for NOx abatement. The LM9000 is also said to deliver 50% longer maintenance intervals, 15% more power and 40% lower NOx emissions compared to competing GTs.

"The LM9000 offers the highest efficiency and power in its range, as well as the longest maintenance interval," said Rossi. These factors maximize production and lower Total Cost of Ownership (TCO). Its attractiveness to the power generation market is mainly in simple cycle for peak delivery to the grid.

The LM9000 is a variation of the core of the GE G90 jet engine. The free power turbine and auxiliaries came from BHGE. This project is helping to establish the methodology for how both companies work together.

Perhaps the largest area of change is in the incorporation of mechanical drive-specific design requirements into the initial phases of a GT development program. Traditionally, the original design requirements of an industrial GT would be primarily for power generation.

Then after some time, the system would be modified for mechanical drive purposes which could cause delays of adoption of the GT into the oil and gas market. Rossi said there is much closer collaboration between BHGE and GE to enable GT architectures to be designed from the onset to maximize value for oil and gas.

"We are driving a culture where we design a gas turbine that can be immediately used for oil and gas," said Rossi. "Both the LM9000 and the NovaLT series were designed for oil and gas."

Under development is a 130 MW-class two-shaft GT designed for mechanical drive LNG applications. One shaft drives the power turbine and the other drives the compressor. It is designed for optimal performance throughout the wide operability range needed by the compression train to deal with changing process conditions and production needs.

This concept is a fit for large LNG trains producing 4 million tons per year. It is likely to be a twin configuration so every train has two GTs.

Rossi thinks this approach could replace old one-shaft Frame 7 machines in LNG that required a helper motor for the start-up. No helper motor will be needed with the two-shaft GT.

BHGE LM9000 gas turbine

Digitalization

Digitalization, too, was a constant theme at the Annual Meeting. Datuk Md Arif Mahmood, Executive Vice President & CEO Downstream of Petronas, said digitalization can help increase value by growing volume at higher margins, as well as improving safety, quality and efficiency.

"Business strategy can no longer be kept separate from digital strategy," he said. "Digitalization must be the number one agenda for the CEO."

This must include a change in the supplier and manufacturer relationship to improve collaboration and heighten results. Digital, said Mahmood, brings insight and competitive advantage. The winners will be those that are agile and can act on digital insights. Those who act fast will come out ahead.

The sheer scale of oil & gas operations is another reason for the rush toward digitalization. Pavel Federov First Vice President of Rosneft, explained that his company has one field that comprises 10,000 wells and 50 data streams per well. Such a huge volume of data requires digitalization to analyze data, detect incipient trends and take the appropriate action.

"Our industry is a laggard in the management and application of data science," said Federov. "Digitalization is now at the top of our agenda. It can be applied to every stage of the production process."

It is all about survival of the fittest, according to Karl Johnny Hersvik, CEO of Aker BP. Companies must change their business processes and slash costs.

"Digitalization is at the heart of this change agenda," he said. "More than implementing new software, it is about applying digital technology to processes."

He cautioned those designing digital solutions to understanding oil & gas operating environments. Offshore is cold, messy and complicated. Those realities must be faced when devising digital solutions.

Aker BP has a fully digitalized rig in the North Sea. Data is taken from all compressors, all turbomachinery, and all systems to the cloud in real time for compilation, analysis and management.

Another company that is delivering real world digital value is Italy's Eni. Shanker Trivedi, Senior Vice President of Enterprise Businesses at chip maker Nvidia said his company has been working with Eni on the world's fastest supercomputer that is designed for seismic, reservoir and basin simulation and analysis.

"We are in the midst of a transition to low-carbon energy, driven by innovation and digitalization," said Alessandro Puliti, Chief Development, Operations & Technology Officer, Eni.

Lubrication monitoring

BHGE's Mulholland also announced a new lubrication condition monitoring system known as VitalyX in conjunction with Emirates National Oil Company (ENOC). It can be deployed in multiple industries using large machinery.

This cloud-based system detects and measures lubricant properties in real-time. As well as being the co-developer, ENOC signed the first order. This offers users and equipment operators a new level of predictive maintenance to enhance efficiency, reduce downtime and improve asset lifetime.

VitalyX can measure chemical and physical properties across a fleet while simultaneously using analytics to convert the data into alerts and alarms to identify potential issues. The dashboard can show fleet-wide data down to the individual asset. Data can be stored either in a shared cloud or locally.

"This will play a key role in revolutionizing lubricant quality testing and physical asset management," said Saif Al Falasi, ENOC Group CEO. "Digitalization is driving the transformation of the energy sector and has contributed significantly to enhancing operational efficiency."

Mulholland explained that VitalyX works by adding sensors to critical assets. The data from these sensors is harnessed to enable condition monitoring, testing and lab work to be done simultaneously.

"The oil tells you something is going on before you notice any vibration," said Mulholland. "You would usually deploy one sensor on a major asset, such as in a gearbox, turbine, engine or on the lube oil mainline."

Instead of waiting days or weeks to hear results from a lab, this system provides immediate results to owners and operators. In the case of ENOC's large fleet of vessels, for example, this means maintenance actions can be done during short time windows where ships are in port.

Sending samples to labs has proved unworkable as some vessels had already sailed by the time the results were received. This cloud-based system is wired into the asset and tied into Bently Nevada SystemOne. Data can be used for trending or micro analysis.

"We track 13 parameters as well as metal particles to offer lab quality analysis on a continuous basis," said Mulholland. "We eventually plan to extend this capability beyond lube oil to fuel oil and other fluids." ■

EXTENDING MEAN TIME BETWEEN OVERHAULS

GAS TURBINES OF ALL KINDS CAN REDUCE DOWNTIME WITH UPGRADES THAT LENGTHEN OVERHAUL INTERVALS

BY GAUTAM CHHIBBER

The oil and gas industry has had to operate for some time in a sustained low-price environment. In light of this, companies throughout the upstream, midstream and downstream sectors have gone to great lengths to reduce the operating and lifecycle costs of assets.

A project was launched, for example, to double the mean time between overhaul (MTBO) for an SGT-A35 GT61 aeroderivative gas turbine (GT). This solution incorporates the SGT-A35 (RB211) Gas Engine with RT61 Power Turbine (PT).

Nearly 40% of these units were covered by long-term service agreements with an MTBO of 50,000 hours. The goal of the project was to increase MTBO for the RT61 PT to 100,000 hours for packages in both power generation and mechanical drive duty.

To validate various analytical predictions, test data was recorded from full-load production pass-off tests. Gas turbine air system data, power turbine air temperatures, and metal temperature data were collected from the outside of the casings at design and off-design conditions. Rotating thermocouple measurements from previous development testing were used for disc metal temperatures and thermomechanical analysis validation.

While this article specifically addresses a use case for the SGT-A35 GT61 aeroderivative gas turbine, this solution could be applied to any GT. For light industrial models, flexible overhaul intervals are available which allow extending the MTBO based on GT loading. For aeroderivative turbines, the potential to extend overhauls based on loading is still in development.

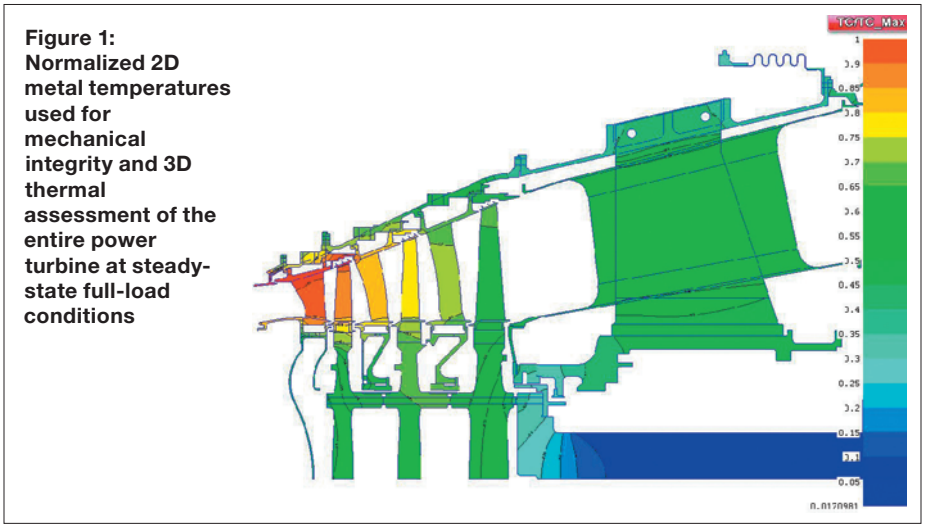


Figure 1: Normalized 2D metal temperatures used for mechanical integrity and 3D thermal assessment of the entire power turbine at steady-state full-load conditions

Thermal analysis

Two-dimensional (2D) thermal analysis was carried out to predict the thermal characteristics of turbine casings, vanes, blades, and discs at rated conditions. It included steady-state peak temperature predictions for component creep stress analysis and thermal gradients at various transient steps for disc low cycle fatigue analysis. This was necessary to understand the impact of thermals on extended MTBO life.

3D finite element analysis (FEA) was used to predict accurate thermal characteristics of hot gas path components, hot gas path radial temperature profiles, and cooling flows. Temperature predictions and mechanical displacements were compared with test results before mechanical integrity assessments were conducted.

A thermal model was run according to development test cycle engine conditions. Transient metal temperatures at various spatial locations were predicted (Figure 1). The effects of the radial inlet temperature profile are evident from the contour plot. The same 2D thermo-mechanical model was run at test conditions, and the predictions were compared with the test data.

It is also useful to compare: transient normalized metal temperatures for a standard cycle between actual test (Figure 2); the normalized metal temperature between test and prediction (SC03) at the stage 1 casing (Figure 3); and the metal temperature contours for stage 1 vane assembly and the rotor assembly at full-load steady-state condition (Figure 4).

A series of additional assessments were carried out. In the cyclic life assessment, a problem area for the Stage 1 blade was found near the hub trailing edge. Low cycle fatigue life and creep damage changed linearly with the turbine entry temperature. Stress and strain were found to not be sensitive to temperature, whereas both fatigue and creep lives are sensitive.

This is primarily due to deterioration in material properties. Sensitivity studies showed that stress and strain are not sensitive to aerodynamic loading on the aerofoil.

Crack propagation

3D crack propagation assessments were completed based on linear elastic fracture mechanics. The summation of minimum initiation life and propagation life met the project requirement for vanes. A creep analysis estimated the creep growth of the airfoil and the time at which it may fail due to the accumulation of creep strain or stress rupture.

Creep life is driven by the time spent at high temperature in loaded condition during normal operation. Creep failure is prevented by imposing a limit on the accumulated plastic strain due to creep. The standard practice is to analyze the aerofoil for the entire life and for a declarable life of 100,000 hours. The analysis showed acceptable creep strain levels for 100,000 hours of operation.

For wear assessment, a significant number of existing units were inspected, and

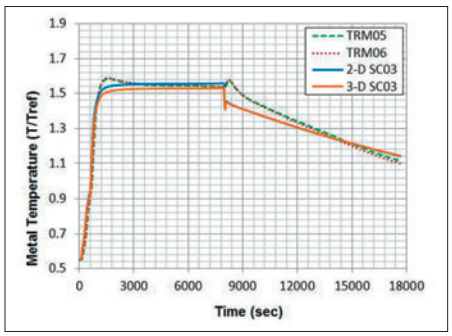


Figure 2: Comparison of transient normalized metal temperatures for a standard cycle between actual test (TRM05/06) and FE predictions (SC03). The thermocouple location corresponds to stage 1 disc front face. The peaks during the acceleration and shutdown are because of the sudden changes in the secondary air system.

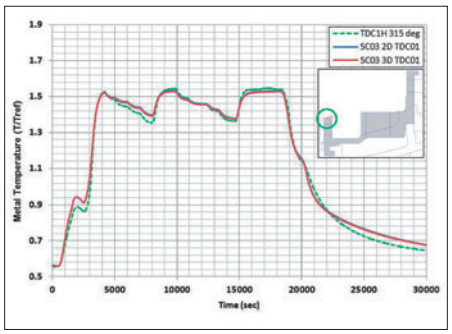


Figure 3: Comparison of the normalized metal temperature between test (TDC1H) and prediction (SC03) at the stage 1 casing. Various off-design points were run to collect the data (see the steps after reaching baseload)

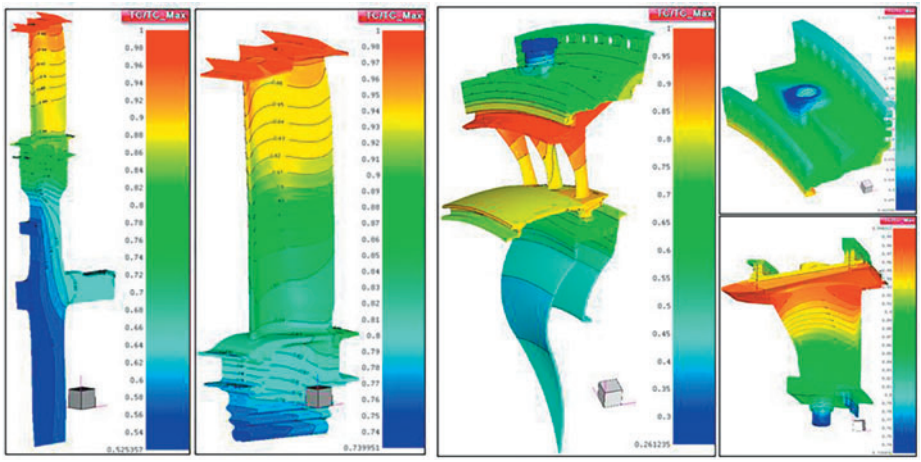


Figure 4: Metal temperature contours for stage 1 rotor assembly (left) and vane assembly (right) at full-load steady-state condition. The casing temperature distribution and the vane temperature distribution are shown on the right side. Temperature distortions because of disc purging flow are evident from the casing contours

existing overhaul reports reviewed. Evidence of minor wear damage was observed at the disc curvic engagement. To mitigate any risk of further damage due to wear, the tie bolt loading on the discs was optimized.

No significant mechanical and microstructural oxidation degradation was observed on the fleet leader unit (50,000 hours overhaul variant). However, substantial uniform oxidation attack was observed, particularly on the first stage vanes and the first stage blade tip seals (Figure 5).

Detailed visual examination and photography were carried out during the rotor disassembly at Siemens overhaul facility in Houston, TX. Deposit and scraping samples were collected from discs, blades, and other components during teardown and returned to the materials laboratory for energy dispersive spectroscopy (EDS) compositional analysis.

Further visual examination and photography were conducted upon the receipt of hardware in the test facility. New stage 1 blades and vanes were also obtained to create a baseline dataset. The lower airfoil regions were sectioned from selected service blades and vanes, and also from the new hardware.

Selected service blades and vanes, along with the new airfoils, were metallographically sectioned at both mid and max-span. Additional sections were taken through the blade tip at mid-chord, vane platforms at mid-chord and other locations as needed.

Scanning electron microscope (SEM) examination on the sections in the un-etched condition evaluated potential hot corrosion and oxidation attack. Tensile and rupture tests from stage 1 service airfoils met the requirements for separately cast test bars of new material. Ultimate strength showed a slight decrease from new to service material and a more pronounced drop in yield strength.

No change in rupture life was observed, although comparisons were difficult to draw given that the new material results were sporadic. Service material data fell between the typical and minimum curves. Tensile and yield strength met the acceptance requirements for service material established based upon the historical data.

No hot corrosion attack was observed. The operating temperature for RT61 PT is between the peak regimes for Type I (high-temperature) and Type II (low-temperature) sulfidation. As such, significant uniform oxidation attack was observed, particularly at the blade tip seal and all vane locations. An oxidation protection coating has been specified to solve this issue.

Certain design measures must be taken to double the MTBO life of the PT — particularly with regards to wear and oxidation protection. The incorporation of these findings into aeroderivatives will help to reduce downtime and improve the reliability of industrial GTs.

By extending MTBO, the number of days of planned downtime over 25 years operation is reduced by nearly 20%, with overhauls required every 12 years instead of 6 years. This can translate into significant cost savings for the user.

Conducting the testing also allowed for the development of a retrofit solution for existing RT61 PT users. In recent years, Siemens has provided the extended overhaul solution to multiple projects, with the PTs operating as expected. ■

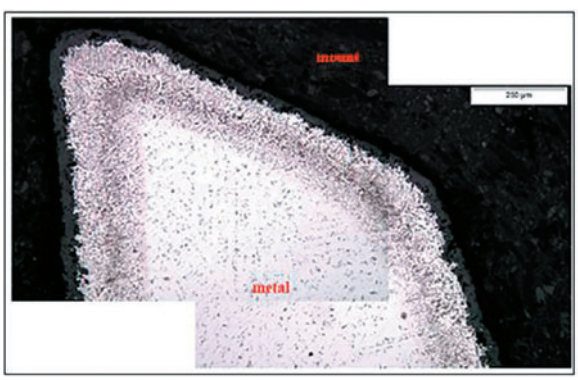


Figure 5: Oxidation depth for the first stage blade tip seal

Gautam Chhibber is Market Team Leader at Siemens. For more information, www.siemens.com/energy

COMPRESSOR UPGRADES

HOW TO USE A ROTOR UPGRADE TO INCREASE PRODUCTION AND REDUCE ENERGY CONSUMPTION

BY ROMAIN BAYÈRE

For energy-intensive industries, such as iron and steel, it is crucial to find ways to update aging equipment, boost production and reduce energy consumption to maintain competitiveness. Energy awareness is reflected in ISO-5000, which defines the framework for industrial plants to manage energy.

Limited energy resources, though, are an important factor to consider in many regions. South Korea, for example, has a limited supply of conventional thermal power and nuclear facilities; it is heavily dependent on external energy sources.

Environmental concerns are also growing in importance. Since 2000, global steel production has almost doubled, reaching 1.69 billion tons of steel in 2017. The sector is the largest industrial emitter of CO_2 in the nation and the second largest industrial user of energy. Although considerable improvements have been made, the iron and steel sector has the potential to further reduce power consumption and emissions.

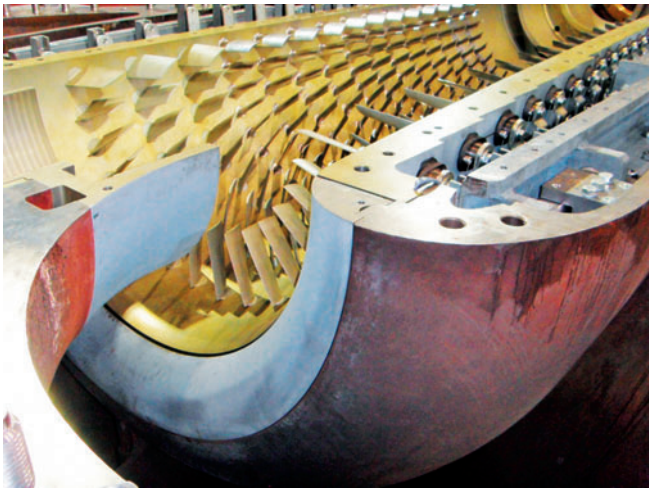
South-Korean steel maker Pohang Iron and Steel Company (POSCO) was the first steelmaker in Asia to acquire the ISO 50001 certification. It must cope with scarce energy sources as well as the strict requirements of the Korean carbon permits trading system. This drove the company to retrofit existing equipment.

Blast furnaces

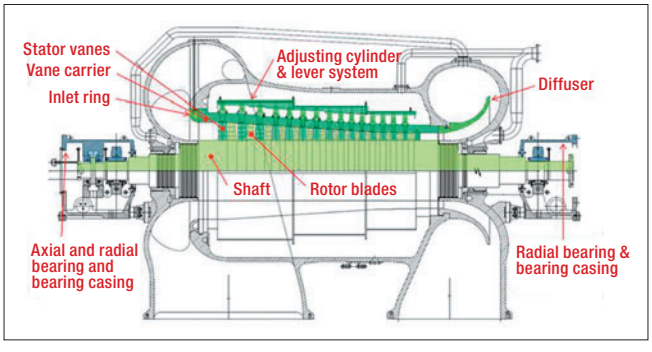
Blast furnaces play a central role in the steelmaking process. They transform raw materials into molten iron and require a lot of power. Air from the atmosphere is enriched with oxygen, compressed and blown into the blast furnace.

In Pohang, three air blowers built between 1978 and 1981 provide air to the third and fourth blast furnaces, which are two of the five large-sized furnaces operated by POSCO. These compressors are driven by electric motors with a power consumption of up to 122 MW.

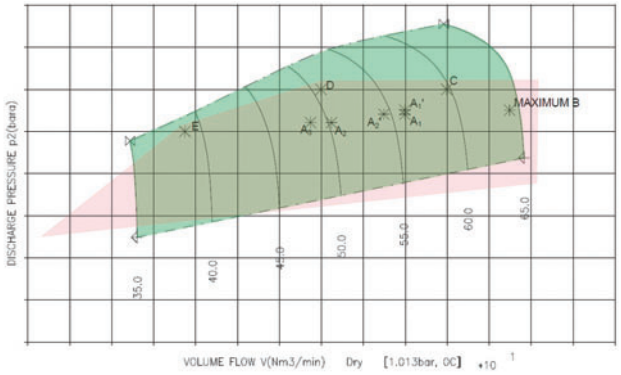
The company decided to upgrade these air compressors. The outer casing was retained, internal parts replaced, and improvements were made to the rotor and stator blades. This approach enabled POSCO to lessen the amount of downtime it would experience compared to the deployment of a new compressor, which would have required a new concrete foundation and modifications outside the machine casing.



The blade carrier was rebladed at the South Korean facility



Design modifications performed on the air compressor. Revamped parts are in red (Source: MAN-ES)



Compressor performance map of POSCO's original (pink) and revamped (green) compressors (Source: MAN-ES)

The implementation of the latest blade technology meant that the number of stages could be reduced from 17 to 14 while maintaining the same discharge pressure. These design modifications were carried out in such a way that the main structure could be retained without adjustments.

The compressor operation envelope could also be increased to higher pressure ratios. New blade roots ensured an easy re-assembly in the circumferential grooves. This permitted the revamp to be completed for all three machines within 12 months.

The project brought energy savings of 6.5%. These types of revamp and modernization projects can be applied to a wide range of air compression trains, many of which remain in operation for more than 40 years. Such revamps applied to a large fleet of machines contribute to more sustainable steel production. ■

Romain Bayère, Head of Revamp Bids & Execution, MAN Energy Solutions Switzerland Ltd. MAN Energy Solutions supplies system technologies that help industrial customers to increase the efficiency of their plants and reduce emissions. Revamps of machinery, upgrades, and modernization of machine trains belong to the MAN PrimeServ portfolio. For more information, visit www.man-es.com

ELLIOTT EXPANDS ITS OIL & GAS TURBOMACHINERY PORTFOLIO

Klaus Brun, Elliott's new R&D Director, discusses the company's capabilities, the aftermarket, market trends, customization versus standardization, and his plans for R&D.

What attracted you to Elliott?

Historically, Elliott has been a technology leader and innovator in the development of advanced and novel turbomachinery products. We are committed to continuing this legacy, and recently made a significant investment in new research facilities, test loops and human resources.

What can you contribute there?

Working in an environment that openly encourages new ideas, novel products and long-term R&D initiatives provides a basis for successful technology development. Elliott looks beyond near-term product evolution and encourages game-changing product development. Few companies offer this type of environment and have this strong a commitment to R&D.

What R&D areas have you outlined for Elliott?

Elliott Group has a new state-of-the-art R&D Center and an active, ongoing R&D program that strives to continuously improve upon existing products and develop new products. Our customers in the energy sector demand products for challenging applications.

To meet their needs, we have initiated several multimillion dollar efforts in the areas of centrifugal compressors, steam turbines and cryogenic pumps that will generate improvements in performance, operability and reliability.

They are primarily focused on our traditional oil & gas markets, but we are also reviewing product options for new markets, such as energy storage, waste heat recovery, geothermal energy, gas-to-liquids and cryodynamic machinery. In the long term we are looking at developing design tools to customize and optimize our compressor, turbine, expander, and pump products to be generally application agnostic.

How are Elliott compressors used?

Elliott offers centrifugal compressors and steam turbine drivers with a primary focus on the petrochemical, refinery and LNG markets. Our vertically and horizontally split centrifugal compressors include some of the largest ever built (flow ranges from 300 m3/hr to giants of almost 500,000 cfm and pressures of 690 barg). We focus on customizing products to provide optimal performance, range, reliability and durability in challenging process applications with complex hydrocarbon fluids.

What are the applications for Elliott steam turbines?

Elliott steam turbines generate power or drive equipment, such as pumps, fans, generators and compressors in all our markets. They range from single-stage machines of several thousand horsepower to 100,000 horsepower. They are often paired with Elliott compressors in refrigeration applications.

Can you discuss recent successes?

We completed several large machinery trains for central Europe and South-East Asia. We are currently working on similar machinery for the Middle East. We have also completed several large compressors for refineries in North America and Asia Pacific.

How much custom engineering is required compared to standardization?

With the widespread adoption of advanced manufacturing technologies and modern engineering analysis tools, the future of turbomachinery design lies in customization of machinery for its desired operating conditions for maximum efficiency, range and life. With advanced design tools and 3-D manufacturing technology, standardization is overly simplistic and can result in machines that are less than optimal for a given application.

What general trends have you observed?

We have noted a geographically broad resurgence of oil & gas in all turbomachinery market segments. In the mid- to long-term, we expect that the refinery, LNG, petrochemical and liquefied gas industries will perform well. We are making sure that our product offering align with these trends.

What aftermarket trends have you observed?

The trend in the turbomachinery aftermarket had been to standardize products into sub-assemblies for modular exchanges, and to centralize repair and overhaul centers to mitigate manufacturer operational costs.

However, we have recently seen a reversal with a desire for customized repair procedures, and the return of local and regionally distributed service centers closer to production plants and facilities. Elliott has major manufacturing facilities in both the U.S. and Japan and more than 20 service centers around the world.

We offer customized repairs to meet client requirements. The aftermarket and Elliott's service offering are a critical piece of our R&D program. We believe that we must support our clients with technology and engineered solutions that allow them to optimize their existing machinery for safety, performance and efficiency.

What do you think of efforts to lower the carbon footprint by focusing on gas instead of oil?

Oil and gas are associated products that cannot be separated. Both are usually produced at the same time, often from the same wells. Elliott offers machinery for both the gas and oil markets. Although we have a product line for upstream and midstream gas transport, we have no intention of deemphasizing or neglecting the oil and liquid products side.

World oil production has grown by almost 30 million barrels per day since the 1980s (almost a 50% increase). It is projected to grow at a similar rate over the next 20–30 years. This oil must be converted into transportation and consumer hydrocarbon products. Elliott stands ready to support this with turbomachinery products. ■

Emuge Turbine End Mills

Turbine machining

Emuge, a manufacturer of taps, drills, end mills and other rotary tools, has introduced a line of end mills featuring geometry designed for the high-performance machining of turbine and bladed components.

Emuge Turbine End Mills offer cycle time reductions and long tool life in challenging forms and materials, including titanium, nickel alloys and aluminum alloys. Complex shapes include wide sweeping radii and deep pocketed cavities. Emuge Turbine End Mills have a tapered flute construction and PVD-applied and heat-resistant coatings.

Emuge.com

Siemens IoT

With the 7KN powercenter3000 IoT (Internet of Things) data platform, Siemens is expanding its digitalization solutions for electrical power distribution in industry, infrastructure and buildings.

Power and system data from up to 40 measuring and protection devices can be collected and transmitted to local energy management systems or directly into open, cloud-based IoT operating systems such as MindSphere.

Data is pre-processed and bundled in packets, which reduces transmission volume. The processing, visualization and evaluation of the data occur using a Web interface powermanager that monitors software or cloud applications. The 7KN powercenter3000 enables even small and medium-sized companies a quick, flexible and economical introduction into cloud-based energy management.

Siemens.com

Nondestructive testing

Nondestructive testing (NDT) provider Zetec has introduced RevospECT HX Pro. This automated inspection analysis software is designed for heat exchangers in the power generation, petrochemical and HVAC industries.

The software retrieves and analyzes eddy current data from heat exchanger tube inspections as it is being acquired, eliminating the inefficiencies and inconsistencies that can come from legacy analysis methods.

RevospECT HX Pro ensures that analysts can classify all types of flaw indications and return heat exchangers to service faster than manual inspection processes. It can also detect small changes that occur over the lifetime of a tube, often missed in a manual process.

RevospECT HX Pro provides upfront analysis parameter configuration which can eliminate performance variability and subjectivity. It is part of a set of integrated technologies that Zetec offers for owners, maintenance managers, and NDT inspectors, including instruments, scanners, probes and software.

zetec.com

CAD software

Open Mind Technologies, a developer of CAD/CAM software, has introduced hyperMILL 2019.1. This new version of its CAD/CAM software suite has features and enhancements including an expanded Finishing Module in the hyperMILL MAXX Machining Performance Package. It also offers a new thread milling module, a new function for reducing calculation times, tool database flexibility, and CAD optimization.

Its Profile Milling technique improves the quality of machined surfaces. A mesh approach standardizes CAM processing, even in cases when the design model has imperfections. The Thread Milling module supports a large number of thread milling types, while simplifying selection and milling direction options. The elimination of cycle recalculation requirements improve processing speed.

openmind-tech.com

Flame detector

Sierra Monitor Corp. has introduced the 39xx series flame detectors. UV/IR model 3986 has a response time as low as 50 milliseconds and high false alarm immunity. This is good for detecting visible and

Fluid cooling

SPX Cooling Technologies has expanded the Marley DT Fluid Cooler product line. New models incorporate finned coils that expand thermal performance and permit dry operation during a broader range of ambient temperatures.

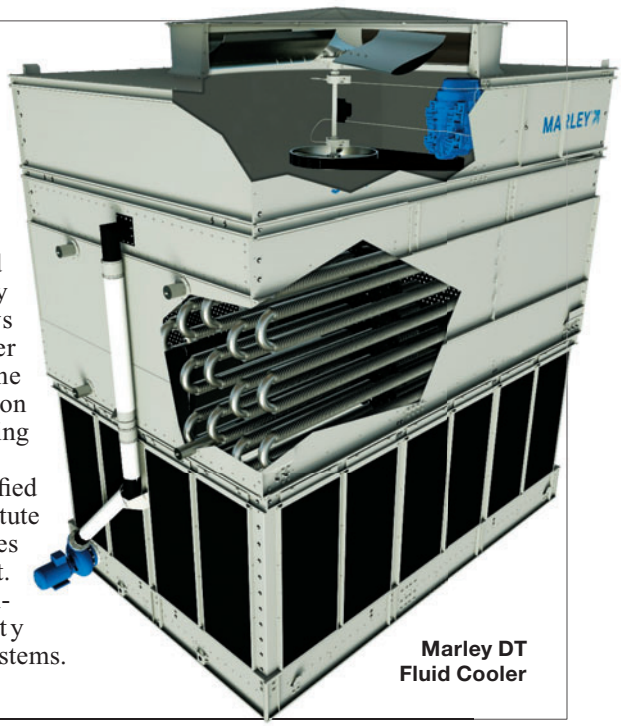
They can more effectively reject heat without evaporating water at ambient temperatures up to 20° higher than with bare tube coils, which helps reduce costs associated with water use, water treatment and pump energy. Other DT fluid cooler models using bare tube coils can satisfy the cold-water setpoint with dry capabilities at colder ambient temperatures.

In colder weather conditions, the fluid cooler offers higher dry operation capacity than fill/coil hybrid coolers. It delivers lower fan energy costs compared to forced-draft coolers and reduces system components compared to combination open tower and plate heat exchanger (PHE) systems.

The Marley DT Fluid Cooler is an induced-draft counterflow fluid cooler. Its closed-circuit design keeps the process fluid in a clean closed loop. Process fluid is cooled by recirculating water that flows over the outside of heat transfer coils as air induced through the cooler evaporates a small portion of the recirculating water, rejecting heat to the atmosphere.

The DT Fluid Cooler is certified by the Cooling Technology Institute (CTI). It is also available in sizes from 8.5 × 9 feet to 12 × 18 feet. It features galvanized steel construction with high-quality mechanical and heat transfer systems.

spxcooling.com



Marley DT Fluid Cooler

non-visible fires. Two options are available; one for hydrocarbon-based fire and one for non-hydrocarbon-based fire.

The Multi-IR model 3976 can monitor five IR bands, with a response time as fast as 260 milliseconds and a high false alarm immunity with a long detection range. Its Fire Event Analysis (FEA) algorithm enables it to discriminate between real fires and non-fire signals.

UV model 3966 has a response time as low as 15 milliseconds, and is available in a standard as well as high-temperature model rated to +125°C. The high-temp model is ideal for turbine enclosures to detect any visible hydrocarbon and non-hydrocarbon fires.

sierramonitor.com

Starrett spring tester

Spring testing

The L.S. Starrett Co. has introduced an affordable spring-testing solution designed for compression and extension springs. The new Starrett S1 Spring Testing Systems were developed for high-volume production testing for users seeking more consistent results over manual testing methods.

Starrett S1 Systems feature test templates that enable the user to create a test set up in seconds using one- and two-point methods, with test targets being load- or height-based. In addition, the small footprint of the S1 System can be deployed in lean manufacturing environments or in situ production areas.

Spring rate, spring constant, free length, solid height and initial tension can be measured, and tolerances can be used to determine immediate pass-fail results, which can be viewed in graphic or tabular formats.

starrett.com

Continued on page 34

Vacuum pump

Atlas Copco has launched a compact dry screw vacuum pump. The DHS 065-200 VSD+ dry screw vacuum pump offers lower lifecycle costs, higher productivity, less energy consumption and easy maintenance.

Built for rapid cycling and continuous operation applications, it is a zero-contamination dry vacuum pump that requires no water or oil cooling. Certified as oil-free in the category 'Class Zero' according to ISO standard 8573-1, the pump is free of oil emissions, including aerosol oil content in the outlet air stream.

The reduced number of parts within the pump combined with the variable pitch screw design help increase efficiency and reduce maintenance.

Atlascopco.com

Atlas Copco vacuum pump

Cortec fuel additives can protect fuel tanks from corrosion

Fuel additives

Cortec has developed the next generation of VpCI fuel additives for corrosion protection of fuel systems. Cortec VpCI-707 is formulated to protect fuel tanks and systems from corrosion and sludge formation without damaging copper and aluminum.

Other benefits are improved water-handling and injector-cleaning capabilities. It does not contain trace metals, chlorides, chromates, nitrites, phosphates or secondary amines.

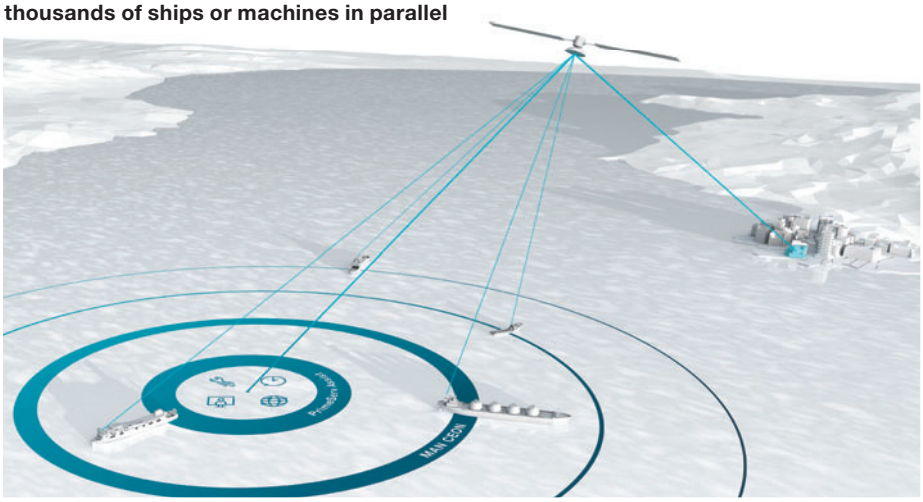
Because of its combined contact-phase and vapor-phase action, VpCI-707 provides corrosion protection to metal surfaces not only in direct contact with the treated fuel, but also in the void space above the fuel line.

This allows it to be applied at a low dose compared to the volume of the tank being protected. VpCI-707 can be added directly to gasoline or diesel fuel in blending, storage, or vehicle tanks. It can also be fogged as a concentrate into dry fuel tanks before storage and shipment.

VpCI-707 can be used for fuel stabilization and corrosion protection for: large or small fuel storage tanks; heavy equipment or vehicles being shipped overseas; equipment operating in harsh industrial or offshore environments; generators or other equipment going into seasonal storage; and industrial plants going into temporary layup.

Cortecvci.com

MAN Ceon sends and processes data continuously and is designed to monitor thousands of ships or machines in parallel



Remote monitoring

MAN Energy Solutions has announced the introduction of a new digital platform called MAN Ceon. It collects and evaluates operating and sensor data and enables the real-time monitoring of marine or power-plant engines, turbines and compressors. The platform integrates data and information from MAN machinery and its operational environment. It can then be analyzed for evaluation and forecasting. It can monitor several thousand installations in parallel.

After connecting to MAN Ceon, users can access the platform via a web application on a PC or mobile device. Data is sent and processed continuously. Encrypted data transmission and a multi-level authorization procedure during login ensure data security. Data can be transmitted to MAN service centers in real time.

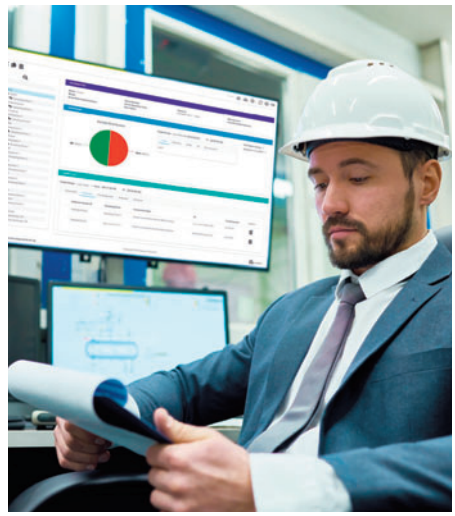
Man-ES.com

Holographic maintenance

Microsoft HoloLens 2 offers a new way of looking at equipment. With PTC's Vuforia software, Howden has created an environment that leverages the functionality of the HoloLens 2 along with its rotating equipment knowledge to help turbomachinery users make informed decisions and optimize performance.

HoloLens technology provides an immersive experience. It offers the ability to grab and rotate holograms like a real object. Microsoft's mixed reality offerings draw digital information out of rectangular screens and allow people to interact with holograms in physical space.

Howden.com



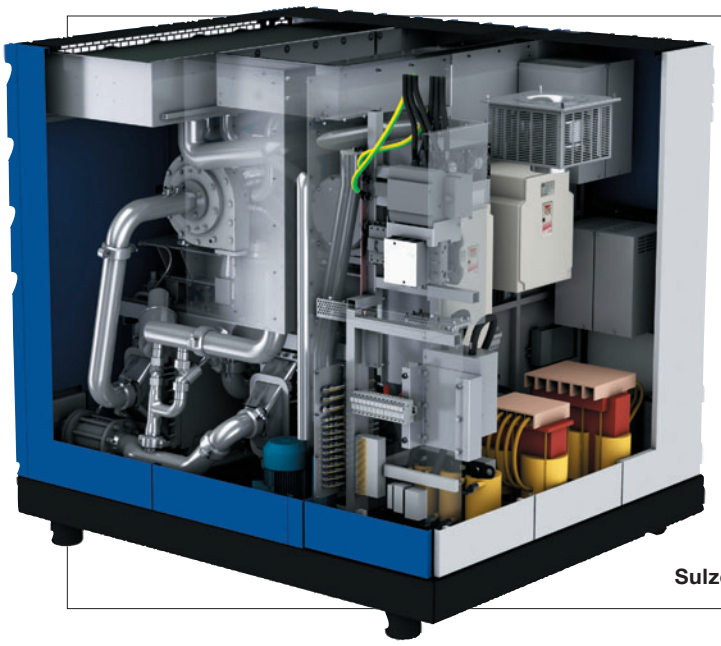
The TruVu 360 for oil analysis

Oil analysis

Ametek Spectro Scientific has expanded its cloud-based TruVu 360 Enterprise Fluid Intelligence Platform with two standalone versions, TruVu 360 Basic and Pro. Both can be installed on a PC or corporate server. The software integrates Spectro Scientific's oil analysis hardware with data acquisition, reporting and information management software, including automatic diagnostics, a dashboard and recommendations for action.

TruVu 360 Basic is for one Spectro Scientific MiniLab on-site oil analysis system for a single user. It is installed on a local PC. TruVu 360 Pro can be installed on a company network server. It features multiple user licenses and provides email notifications about oil analysis.

spectrosci.com



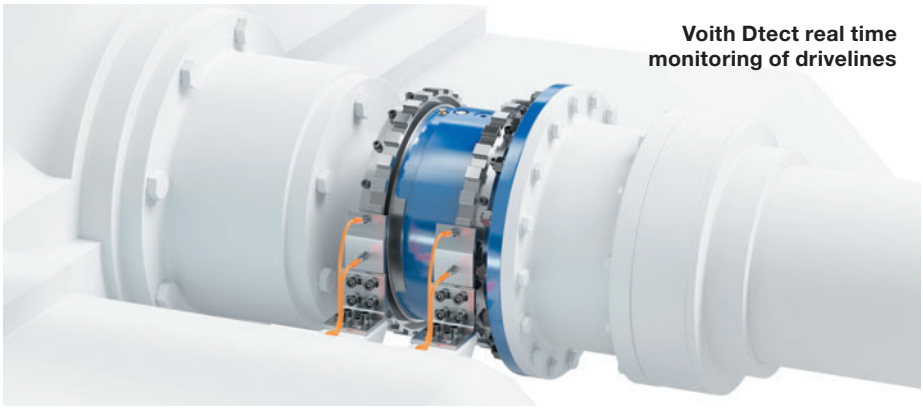
Sulzer HSR high speed turbocompressor

High-speed compressor

Sulzer and Tamturbo have joined forces in high-speed compression. Tamturbo focuses on the oil-free compressed air market. Its turbocompressors produce oil-free air without contamination. It typically supplies 3-10 bar pressure to industrial compressed air networks.

The companies are collaborating to bring the benefits of high-speed technology in air compression to those in need of oil-free air. New products will replace oil-free screw compressors with Sulzer HST turbocompressors and equipment with active magnetic bearings. The application of variable frequency electrical supply and advanced control technologies also play an important role in these products.

sulzer.com



Voith Dtect real time monitoring of drivelines

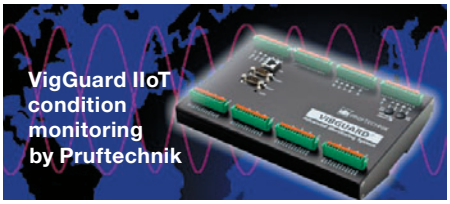
Driveline monitoring

Voith Dtect is a monitoring system that provides real-time data of driveline performance and coupling status. Based on this, the operator can take actions to prevent potential problems and avoid downtime. Dtect enables comprehensive monitoring of a driveline's torque limiting couplings. It was designed to work with couplings, such as Voith's SmartSet, which serve to prevent machine damage in high-value rotating equipment. It is also possible to upgrade existing couplings with the intelligent system.

Through continuous measurement of the slip angle, Dtect identifies and monitors coupling slippage caused by high torque peaks in a driveline. This allows users to adjust the load of the driveline or perform a controlled shutdown, if required. The system uses an updated quadruple sensor that increases the sensing range without affecting measurement resolution.

Dtect also makes it possible to monitor multiple couplings at the same time. It assesses each coupling individually and communicates parameters via a common interface. Equipped with Modbus TCP/IP communications, Dtect can be integrated into established process information networks.

voith.com



VigGuard IIoT condition monitoring by Pruftechnik

Internet of Things system

VibGuard IIoT condition monitoring by Pruftechnik with 16 analog channels for online machine and plant monitoring has an interface that allows it to be integrated in the Internet of Things (IIoT). It has global data availability, reduced data volume, and improved data security.

In addition to the standard modbus interface, the VibGuard IIoT features an interface for IoT for permanent online machine monitoring. The system can be networked. Vibration measurement data can be directly linked with other measurement data (e.g., weather, flow rate, and so on.). The new VIBGUARD IIoT with 16 analog channels was developed for pumps, conveyor belts, fans, mixers, compressors and centrifuges.

pruftechnik.com ■

AD INDEX

POLYTROPIC EFFICIENCY EXPLAINED

Recently, while attending a conference, I was asked by an audience member, "What is polytropic compression?" It's not an easy concept but I tried as best as I could to explain that it is a reversible (thus ideal) process which involves both heat and work transfer.

Specifically, for polytropic compression processes, one divides the thermodynamic path from suction to discharge pressure and temperature into an infinite number of steps with each of these steps having the same (polytropic) efficiency. That's why polytropic efficiency is also sometimes called small-step efficiency.

Each polytropic step includes an equal infinitesimally small heat exchange to compensate for temperature increase due to entropy. For example, viscous losses (aka irreversible) in the real compression process are compensated using heat addition, such that the efficiency for each step remains the same. Importantly, both the isentropic and the polytropic process are ideal processes, and as such reversible.

A physical perspective

That's a rather esoteric explanation with little real world meaning. What does this actually do for me? It's complex and completely meaningless from a physical perspective. I am yet looking for an engineer in our industry who can properly explain what a "physical" polytropic efficiency actually is.

As young engineers many years ago, we mostly used the isentropic compression process as reference, primarily because most of the textbooks use it. Once I entered the oil and gas industry, I realized that most compressor manufacturers actually did use polytropic efficiency, and because nobody wanted to numerically divide the process into an infinite number of steps, approximate methods for efficiency determination are used.

Isentropic efficiency is seldom mentioned in our industry and the next editions of industry compressor test codes and compressor standards will likely not even include isentropic efficiency.

On the other hand, isentropic efficiency is incredibly simple. An isentropic compression process directly relates the amount of energy of compression, such that efficiency is proportional to power required by the compressor.

For example, if the compressor loses 3% in isentropic efficiency, the power required by the compressor is 3% higher. It's that simple. Even the thermodynamic definition of isentropic efficiency is relatively simple: It's the ratio of the enthalpy (energy per unit mass) difference between an ideal isentropic (no entropy change) versus an actual process.

On the other hand, polytropic efficiency relates to compressor power required via a complex algebraic equation for ideal gases and an iterative process for non-ideal gases. If the polytropic efficiency of a compressor drops by 3%, I have no idea how that affects the compressor power.

From a thermodynamic process perspective, the isentropic process is more intuitive, easier to understand, and logical. Isentropic efficiency relates actual compression with an ideal compression that does not exchange heat with the environment, (adiabatic) and does not create any losses (no viscosity and reversible).

Adiabatic and reversible means it is isentropic. Therefore, the isentropic process is the adiabatic process that does the compression with the least amount of work possible.

For aerodynamic comparisons, polytropic head and efficiency appear to have some advantage, at least theoretically. Specifically, in a performance test where the gas used is different from the gas at site, one wants to create a situation where the velocity polygons in all stages are the same for test and site.

This can be accomplished if, as a minimum, the actual flow divided by the running speed, the ratio between inlet and discharge flow and some characteristic Mach number are the same. However, the only way to retain similarity of the velocity polygons is by having exactly the same actual work (divided by the square of the speed) done by each component, and neither the isentropic, nor the polytropic work assure that.

Polytropic work is helpful because it preserves the discharge temperature of the overall compressor and the inlet and exit gas conditions are maintained. However, the polytropic path assumes constant efficiency along the entire compression path while in an actual compressor, each stage, and each sub-component, has a different efficiency.

On the other hand, when we look at the process from the perspective of the people who buy these compressors, polytropic work is irrelevant. For a compression process, we typically define the inlet conditions, and the desired discharge pressure.

This is fully defined by the isentropic work, but not by the polytropic work. Yes, polytropic work will provide the actual discharge temperature, but the polytropic work is, like the isentropic work, not equal to the actual work.

Fundamentally the only real value that polytropic efficiency provides is for the compressor designer. Specifically, when quantitatively comparing the aerodynamic performance of multistage compressors it is nice to not have to normalize efficiencies back to an average stage performance or to actually have to compare stage-by-stage performance.

From a holistic compressor performance perspective, especially from the point of view of how much power a compressor driver needs to provide and how much energy will be expended compressing the gas, polytropic efficiency is mostly useless.

So why do compressor designers prefer polytropic over isentropic? Polytropic efficiency is always higher than isentropic efficiency and makes their compressors look better. And, yes, it allows comparing the aerodynamic quality of a compressor that has a pressure ratio of 10 for some process, with another compressor, for another process with a pressure ratio of 4.

However, once I compare two compressors for the same process conditions, all I care about is how much power they consume. Of course, it's much nicer to discuss an 85% efficient high-pressure ratio compressor than revealing that the compressor is only 75% energy efficient and 25% is lost to heat generation. The higher the compression ratio the compressor has, the higher the difference between isentropic and polytropic efficiency, and polytropic will always be higher. ■

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