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THE EVOLUTION OF TURBOMACHINERY CONTROLS

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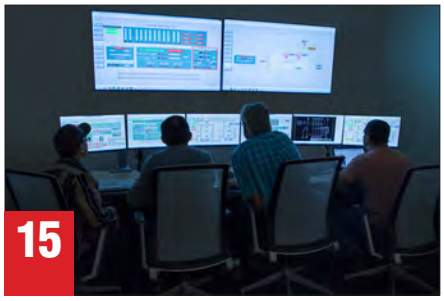

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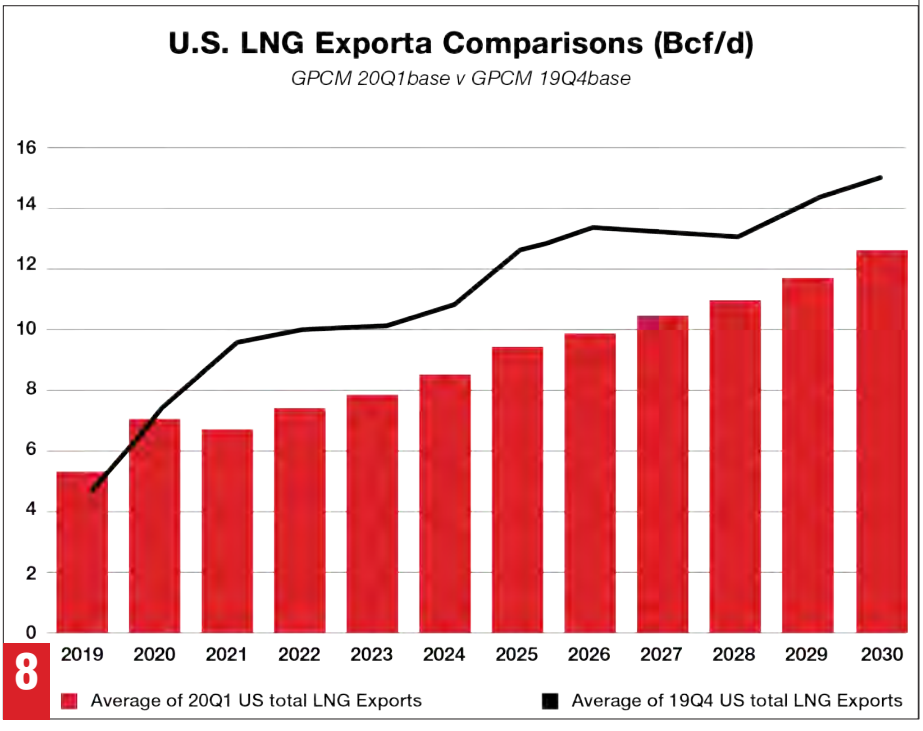

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A wave of innovation has swept across the controls and instrumentation field recently. We've talked about these technologies for years. But they were never quite ready for prime time. Many of them have now reached sufficient maturity to be trusted by plant operators and fleet owners.

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EDITORIAL & BUSINESS OFFICES

Turbomachinery International
485 F Suite 210, Rt. 1 South
Iselin, NJ 08830
Tel: 203-523-7053

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WHO IS IN CONTROL?

Control – always a hot topic. The reds and blues fight for control of Congress. There will be a monumental battle for control of the U.S. come the November election. And of course, there are currently a whole lot of people telling us what we can and cannot do, where we can and cannot go and who we can meet – if anyone at all.

Like political control, turbomachinery controls are dynamic and changing. That is the subject of our cover story. A wave of innovation has swept across the controls and instrumentation field recently. We've talked about many of these technologies for years. But they were never quite ready for prime time. Many of them have now reached sufficient maturity to be trusted by plant operators and fleet owners.

The Industrial Internet of Things (IIoT), digitalization, microprocessors, new software platforms, the cloud, advanced analytics, machine learning, wireless technology, mobility, connectivity, augmented reality, virtualization, artificial intelligence, cybersecurity, big data, Software-as-a-Service and many other breakthroughs have advanced the field like never before. This has given rise to enhanced capabilities for remote monitoring and operation, digital twins, remote field service, maintenance automation, real-time plant and fleet management and tighter inventory control. Those harnessing these tools report fewer unscheduled outages, and longer plant and equipment lifespans.

> **"Turbomachinery software and controls are destined to be a hot area of the market for some time to come.**

In these times of dire forecasts about turbine sales and slow market recoveries, it appears that software and controls are destined to be a hot area for some time to come. Those holding onto aging turbines without replacement should at least want to operate them with the latest controls. Similarly, the business world at large is adopting these tools in a big way. Whether from head office, partners, customers or rivals, pressure will inevitably mount to adopt the latest control and instrumentation software capabilities. Those looking for market growth, or for an avenue to replace lost revenue, would do well to look into how they can utilize these technologies to add value, bring about greater connectivity and better serve their users.

The issue is otherwise packed with goodies. We have a follow-up story to our May/June cover story on Covid-19. Things appear less grim and many are seeing a slow return to normality. There is also an overview article on Power-to-X: an umbrella term for various approaches to the conversion, storage and reconversion pathways that take advantage of surplus electric power from renewable energy (typically from solar during the day or wind at night). The X stands for the type of energy into which the electricity surplus is being converted. This is generally gases, liquids or heat.

Further feature article topics include how to upgrade centrifugal compressors using inlet guide vanes, a more efficient way to conduct LNG regasification, offshore air filtration, how to repurpose aging turbines into synchronous condensers, and best practices for boiler and HRSG upgrades. Columns take up subjects such as a summary of recent webinars, gearbox trends, turbomachinery startup and post-commissioning, and the differences between the storage and transportation of energy.

Changes

After close to two decades at the helm, our publisher Richard Zanetti has retired. Richard's leadership revived the fortunes of the magazine and made it what it is today. Richard is replaced as publisher by Mike Tracey, a veteran of the publishing field.

Further changes at the magazine: Our new associate editor Rory Pasquariello has taken over the online and newsletter functions from Kalyan Kalyanaraman. Kalyan is thanked for his many years of service. You can find Rory's email address in the masthead. Please add him to your press distribution list.

We hope to have a chance to visit your booths sometime in the near future – perhaps at PowerGen, if not before. Wishing you all good fortune in your efforts to emerge from this period of economic turmoil.

Let's get back to work! ■

Drew Robb

DREW ROBB
Editor-in-Chief

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U.S. LNG EXPORTS EXPERIENCE FALLOUT FROM COVID-19 AND THE OIL PRICE COLLAPSE

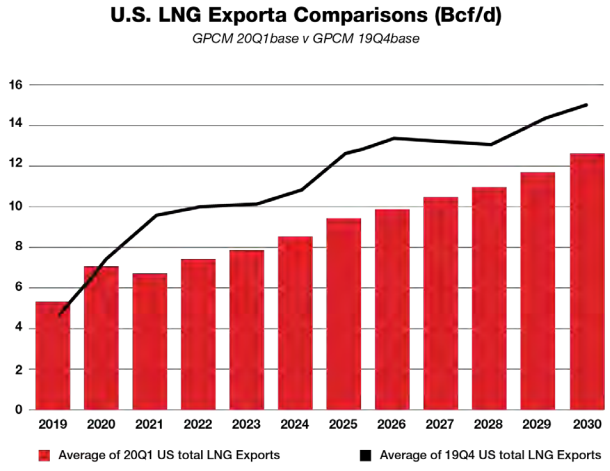
A revised forecast has come out on the natural gas market primarily due to the Covid-19 pandemic and the brief crude oil price war initiated by Saudi Arabia due to the failure of extending OPEC+ production curtailments. These led to an unprecedented collapse in crude oil prices as well as oil rig numbers declining at the most rapid pace ever. As a consequence, gas production has declined as well. Analyst firm RBAC, therefore, predicts that gas prices will trend higher, breaching the $3.00/MMBtu in January 2021. This will be driven by domestic production declines, especially in the oil-centric basins, and to a lesser extent demand rebounding, albeit at a modest pace.

An anticipated dramatic supply curtailment will see U.S. natural gas production falling from nearly 97 Bcf/d in February 2020 to 88 Bcf/d during the June 2020 to August 2020 period. It could take some time for production to rebound.

This is impacting U.S. LNG exports. With global gas demand dropping dramatically, U.S. LNG exports over the next several years are expected to be significantly lower than previously forecast. The latest integration of RBAC's modeling system suggests approximately 1 Bcf/d lower exports though the balance of 2020, while the divergence grows to over 3.5 Bcf/d during the summer of 2021 and approaches nearly 5 Bcf/d by December 2021. This dramatic drop is due to much higher prices coupled with lingering global gas demand weakness which makes U.S. natural gas less competitive globally.

This does not mean that U.S. natural gas will remain uncompetitive longer term. In fact, prices remaining in the $3.00 to $3.50/MMBtu range throughout 2021 and 2022 provoke the supply response necessary to moderate prices, said RBAC. Simultaneously, global demand returns to more normal levels leading to a rebound in U.S. LNG exports thereafter.

U.S. domestic gas demand has been impacted by Covid-19, though not as much as crude and refined products have been due to their greater use as transportation fuels (diesel, jet fuel, and gasoline). There is, however, some spill-over effect from transportation fuels demand destruction to natural gas industrial demand. Specifically, refineries, petrochemical plants, auto manufacturing and other industrial demand related industries have significantly reduced operations – some have ceased operating all together. This shuttered demand is likely to remain lower than normal until 2022 – 2023.



RBAC's forecast of U.S. LNG exports made in Q4 2019 compared to the latest forecast in red. Source: RBAC's GPCM Natural Gas Market Forecasting System outlook.

MHPS digest

Mitsubishi Hitachi Power Systems (MHPS) bagged orders of 2,638 MW in the first quarter of 2020, which brought its market share to 28.5%. Sales in both the advanced class and aeroderivative segments contributed the most. One order was for two renewable hydrogen-capable JAC gas turbines (GTs) for the Intermountain Power Agency in Delta, Utah.

MHPS received an order for a steam turbine (ST) for the Datan Power Plant in Taoyuan, Taiwan. The equipment will be used to convert simple cycle generators to combined cycle, increasing capacity from 600 MW to 900 MW. Combined cycle operation is scheduled to begin in November 2023.

MHPS has received an order from Chinese firm Baotou Steel Group for two blast furnace gas (BFG)-fired 165 MW GTs. These combined cycle power plants (CCPPs) with M701S (DA) X series GTs utilize BFG produced in the steel plant. BFG-fired CCPP units comprise a GT, heat recovery boiler, ST, power generator, gas compressor and auxiliary equipment. BFG has a low-calorie rating compared to natural gas. Special combustors are required.

Blade testing

The Electric Power Research Institute (EPRI) has evaluated the application of an inspection technology developed for jet aircraft engines to help operate industrial and power sector GTs more safely and reliably. The evaluation focused on applying Vibrant Corporation's Process Compensated Resonance Testing (PCRT) for hot section blades, EPRI found that the technology's use can decrease the risk of blade failure and extend component life. Model-specific blade frequency characteristics were used in testing.

PCRT is a non-destructive, ultrasonic technology for qualitatively evaluation of blade material state, structural integrity and dimensional variations. It applies statistical metrics and pattern recognition tools to pick out parts that differ from the rest.

Opra commissioning

Opra China successfully commissioned an OP16 GT using a titanium dioxide flash drying system at the Lomon Billions project in China's Henan Province. The unit can achieve more than 85% efficiency. Heat is converted into electric energy and low-grade heat is used for drying.

Voith digest

Voith Group and Moog, both developers, manufacturers and suppliers of electric, hydraulic and hybrid drive solutions, have formed a joint venture known as HMS – Hybrid Motion Solutions based in Rutesheim, Germany. The joint venture aims to expand the hydrostatic servo-hydraulics business in various industrial markets. The joint venture will focus on research and development, design and assembly as well as service.

Voith successfully completed the acquisition of ELIN Motoren, an Austrian high-tech company in the field of electric motors and generators. ELIN Motoren will remain independent as a business and will continue to be active using the established ELIN Motoren brand. Customers of both Voith and ELIN Motoren will continue to have access to the same sales channels. ELIN Motoren manufactures electric motors and generators in small series, as well as individualized solutions for industrial applications. In this area, the company focuses on electric machines, motors in the low-voltage, medium-voltage but also in high-voltage range, and generators, in particular for wind energy and decentralized energy generation.

Kobe Steel has turned Chinese affiliate Wuxi Compressor into a subsidiary

Kobe Steel subsidiary

Kobe Steel announced that a Chinese affiliate, Wuxi Compressor has become its subsidiary after acquiring additional shares in the company. Based in Wuxi, Jiangsu Province, Wuxi Compressor manufactures designs and sells non-standard (process gas) compressors, a core component used in petroleum refining, chemical and natural gas plants.

In response to the growing demand for non-standard compressors in China, Kobe Steel acquired a 44.3% equity share of Wuxi Compressor in 2011. With additional 25.7% of shares acquired, Kobe Steel is the majority owner. By turning it into a subsidiary, Kobe Steel will be able to provide more flexible business operations and strengthen its marketing capabilities while offering better service in China. It aims to meet the growing demand for non-standard compressors in China.

Kobe Steel is one of the few manufacturers in the world that supply three types of major compressors: screw compressors, reciprocating compressors, and centrifugal compressors. In particular, Kobe Steel has the largest market share for non-standard screw compressors. The Kobe Steel Group has manufacturing locations for non-standard compressors in Japan, the United States and China, along with sales and service locations in Germany, the United Arab Emirates (UAE), Brazil, the Philippines and Singapore.

Renewable natural gas

U.S. Gain has completed a renewable natural gas (RNG) supply agreement with the Port of Seattle. RNG will be used to heat Seattle-Tacoma International Airport (SEA) and power its fleet of buses. RNG is produced from methane captured during the decomposition of organic materials at agricultural farms, landfills and wastewater treatment plants. It is cleaned and conditioned to meet pipeline standards and injected into existing natural gas distribution pipelines.

GE completed repairs and upgrades at a plant in Russia.

GE digest

GE completed a major inspection of the Siemens's 60 MW SGT-800 gas turbine (GT) installed at the Ufa TPP-2 CCPP, owned by Bashkir Generation. The 519-MW Russian plant is in Ufa, Republic of Bashkortostan. Component repairs were carried out at the GE Energy Technology Center in Kaluga (150 kilometers south of Moscow). The inspection included the modernization of elements of the turbine unit, as well as first startup, commissioning and tuning, test validations and safety measures.

GE provided two synchronous condensers and flywheel units to Italian grid operator Terna. for the Brindisi substation in southern Italy. Each unit will supply reactive power of up to +250/-125 MVAr and 1750 MWs inertia to provide grid stability. They will be installed along the transmission system to produce or absorb reactive power to keep the power flowing consistently. GE's synchronous condensers also regulate energy parameters, regulate voltage, improve the energy factor, and increase the inertia of the grid. Scope of supply includes design, civil works, supply, installation and commissioning of two electrical two-pole generators, step-up transformers, generator circuit breakers, electrical and mechanical auxiliaries and balance of plant, protection and controls systems, monitoring and diagnostic systems, as well as 20 years of maintenance. Each of the generators will be equipped with a flywheel to respond to the inertia requirements from Terna. In total, GE's eight synchronous condenser units will supply up to 1,820 MVAr of reactive power with a value of 10,500 MWs of inertia.

GE installed a new rotor and a compressor upgrade on a GE 9F.03 GT at Tirreno Power's 1,200 MW Torrevaldaliga Sud Power Plant near Rome. The project goal was to enhance reliability and availability. Engineering enhancements reduce the impact of degradation that naturally occurs with time on rotor components and improves lifespan.

Edison has selected GE's advanced gas path (AGP) technology for its Torviscosa 780 MW power plant, located in Torviscosa, Friuli region, Italy. The hardware upgrade applies to two GE 9F.03 GTs at Torviscosa to increase the plant's output by more than 6% and its efficiency by around 1%.

GE has received an order for its GT26 HE gas turbine upgrade with Japanese power producer JFE Steel at its Chiba Power Plant in Japan. Plant output is expected to increase by more than 10 MW, with efficiency increasing by more than 1%. The upgrade introduces technology from GE's HA GT, as well as additive manufactured parts, streamlined aerodynamics, new materials and better combustion dynamics. The upgrade is expected to be completed in Baden, Switzerland and shipped for installation in 1Q 2021 and is expected to be operational by mid-2Q 2021.

Doosan digest

Doosan Škoda Power installed a DST-S20 ST with an output of 200 MW at the Punta del Tigre combined cycle power plant near Montevideo, Uruguay. Doosan Škoda Power worked with Hyundai Engineering & Construction, a Korean engineering, procurement and construction (EPC) company. In addition to the ST (with double-casings, condensing with reheat and the radial steam outlet from rear low pressure part into the water condenser), the manufacturer supplied a generator, a control system and field instrumentation, an oil system, piping, a gland steam system and drain system.

Doosan Škoda Power has made top management changes. Sukjoo Kang replaced the long-time General Director, Jiří Šmondrk. Global restructuring is now underway. In addition, the new Chief Operational Officer (COO) is Daniel Procházka.

Doosan Škoda Power is supplying two 50 MW STs with controlled extractions, gearboxes and generators to the Volkswagen factory in Wolfsburg, Germany. Requirements for operation within the automobile factory differ considerably from standard supplies for conventional or industrial power plants, as it generates electrical energy and but also supplies steam to other technologies of the factory.

Doosan Škoda Power steam turbine installation in Uruguay.

Siemens digest

Siemens Gas and Power has been selected to supply a range of compression and power generation equipment for the Balikpapan Refinery located on Borneo Island in East Kalimantan, Indonesia. The facility is owned and operated by PT Pertamina (Persero). The project involves the construction of a residual fluid catalytic cracker (RFCC) unit with a capacity of 90,000 barrels per stream per day (bpsd); a liquefied petroleum gas (LPG) sulfur removal unit; a propylene recovery unit; and an 80,000 bpsd middle distillate hydrotreater. Scope of supply includes four GTs, 17 reciprocating compressors and a single-stage, hot gas expander. Compressor models include eight HHE-VL compressors, two HHE-FB compressors, four HHE-VG compressors, and three HSE compressors, as well as four SGT-800 GTs and five SST-600 STs. The hot gas expander will recover waste heat (i.e., flue gas) from the RFCC reactor to produce 20 MW of power to drive an air blower and ST. This will increase refinery output from 240,000 barrels per day (BPD) to 360,000 BPD.

Siemens Gas and Power was awarded a contract to supply three SGT-300 industrial GT generators, three mechanical drive SGT-300 GTs and three Datum centrifugal compressors for the Petronas Kasawari Gas Field Development Project in the South China Sea, offshore Sarawak in Malaysia. The customer, Malaysia Marine and Heavy Engineering (MMHE), has formed a joint venture with TechnipFMC to execute this work, with Petronas as the end user. The three SGT-300 units will have dual-fuel capability, and each will have a power capacity of 7.9 MW. The three mechanical drive GTs will produce 9 MW to drive the compressors to compress and export sales gas to the existing riser platform nearshore, before delivering gas to the LNG complex. The units will be delivered to the customer by Q1 2023.

Siemens Gas and Power was awarded a contract from CCZ JV (a joint venture between Chiyoda International, McDermott International, and Zachry Group) to supply three cryogenic boil-off gas (BOG) compressor trains for the Golden Pass LNG export terminal in Sabine Pass, Texas. The facility will be integrated into the existing Golden Pass LNG import terminal. It will include the construction of three liquefaction process trains, each with a nominal output of approximately 5.2 million metric tons per annum (MTPA). Scope of supply covers the engineering, manufacturing, and testing of the three, single-shaft centrifugal BOG compression packages, along with all installation and commissioning. Each of the compressor packages will be driven by a 6.8 MW electric motor. Manufacturing, testing, and packaging will take place in Duisburg, Germany. Scope also includes a frame agreement to supply all low-voltage electric motors and electric variable speed drives (1 – 200 horsepower) and all medium-voltage (250 – 1,500 horsepower) electric motors. In addition to the BOG compressor trains, Siemens Gas and Power will also provide ST generator sets for the Golden Pass LNG export terminal.

Siemens Gas and Power was awarded a contract to supply two SGT-400 GT compression packages for Midcoast Energy's CJ Express pipeline expansion project in east Texas. WHC Energy Services, supported by Universal Pegasus, will be the EPC provider. The two mechanical-drive compression packages can produce 39,000-horsepower. The SGT-400 GTs will be packaged at Siemens Gas and Power's Telge Road facility in Houston, Texas, while the compressors will be built at the company's facility in Olean, N.Y., USA. The first compression trains will be shipped later this year to support commercial operation for early next year.

Four Siemens SGT-800 gas turbines were ordered for the Balikpapan refinery in Indonesia.

Siemens Gas and Power was selected to provide three 33 MW SGT-700B GTs for a Long-Term Program (LTP) with Ascend Performance Materials' nylon intermediate and specialty chemicals facility in Decatur, Alabama. This will allow Ascend to retire assets that currently provide process steam. The shift to GTs for steam generation is part of a sustainability strategy. Siemens will perform all scheduled outages for eight years. At the time of the first inspection, the B-series generators will be upgraded to C-series models (35 MW rating) to operate in a cogeneration application. Commissioning is expected in Q4 2021.

Vattenfall Wärme Berlin commissioned the Berlin-Marzahn CHP plant, which was built by Siemens Gas and Power as general contractor. It is a natural gas-fired CCPP with district heating extraction. It provides electricity for up to one million inhabitants and supplies around 150,000 households with district heating. The plant has an electrical capacity of 260 MW, a thermal capacity of around 230 MW and a maximum fuel efficiency of 92%.

Hydrogen turbine

The HyflexPower project aims to demonstrate a GT running on 100% hydrogen. Excess renewable electricity will be stored in the form of green hydrogen. During periods of high demand, hydrogen will be used to generate electrical energy. This is part of what is known as Power-to-X (or P2X), i.e., converting electricity into another energy vector. The X in this case is hydrogen.

The project consortium is made up of Engie Solutions, Siemens Gas and Power, Centrax, Arttic, German Aerospace Center (DLR) and four European universities. It is funded by the European Commission under the Horizon 2020 Framework Program for Research and Innovation. If successful, it will be the first industrial-scale power-to-X-to-power demonstration. It will be launched at Smurfit Kappa PRF's recycled paper manufacturing site in Saillat-sur-Vienne, France. The purpose is to prove that hydrogen can be produced and stored from renewable electricity and that up to 100% can be run in a GT in combined heat and power (CHP) plants. An existing Siemens SGT-400 GT will be upgraded to convert stored hydrogen into electricity and thermal energy.

Engie Solutions operates a 12 MWe CHP facility at the site that produces steam for manufacturing. The project will begin with a mix of natural gas and hydrogen and gradually increase the quantity up to100% hydrogen by 2023. Siemens Energy will supply the electrolyzer for hydrogen production and develop the hydrogen gas turbine. Centrax will upgrade the package.

High-temperature blades

The U.S. Department of Energy has announced up to $28 million in funding for a new Advanced Research Projects Agency-Energy (ARPA-E) program, Ultra-high Temperature Impervious Materials Turbine Efficiency (Ultimate). The program will develop and demonstrate blade materials that can operate in the high temperature and high stress environments. Projects will target applications in power generation and aviation. The Ultimate program aims to improve GT efficiency by increasing the temperature capability of materials. It targets operation continuously at 1300°C or turbine inlet temperatures of 1800°C or higher when coatings are used.

Man ES compressor trains being installed at a facility in the Netherlands for CO2 storage.

MAN digest

MAN Energy Solutions (ES) in Berlin has been awarded a contract for the engineering of three RG compressor trains for a carbon capture, utilization and storage project in the Netherlands. It will store 2.5 million tons of CO_2 per year under the North Sea, captured by various companies in the Rotterdam port area. A pipeline will run for around 30 km to a platform off the Dutch coast. CO_2 will be pumped into the exhausted P18 gas fields. Storage capacity should be about 37 million tons. The captured CO_2 can also be used for industrial applications, such as greenhouse horticulture to foster faster plant growth.

The MAN ES scope of work covers the engineering of two RG 25-4 and one RG 31-4 compressor trains with an order for three additional units intended at a later stage. The trains will be located at a compressor station on Maasvlakte, the man-made, western extension to Europoort. CO_2 will be pressurized to ~132 bar to transport and inject the gas into fields more than 3,200 meters below the sea. The compressors can handle up to 285 tons of CO_2 per hour, depending on how many units are running. CO_2 storage should begin by the end of 2023.

MAN ES will supply two MST050 STs, each with a gearbox, generator and auxiliary components, for a CHP plant in Leipzig, Germany. The STs, with a total power output of roughly 56 MW, will help supply the city with electricity and heat. Condensation heat that is not used to generate electricity is utilized in the citywide district heating network.

Turboden manufacturing

The Italian Organic Rankine Cycle systems supplier Turboden has expanded its internal production to include the production of bundles for air coolers and their on-site assembly. These bundles consist of an assembly of tubes, headers, side frames and tube supports that make up air-cooled condensers, a core component of an ORC plant. This helps to optimize ORC design and shortens lead times

No engineer left behind

To support the turbomachinery community, SoftInWay has started a "No Engineer Left behind" program. Any engineer that lost a job to the Covid-19 epidemic can reach out to learn@softinway.com and receive free access to the educational version of the AxSTREAM platform, and the company's E-Learning classes on topics such as turbomachinery design, system level analysis/modeling, and rotor dynamics.

European Power-to-X consortium

"FLEXibilize combined cycle power plant through Power-to-X solutions using non-CONventional Fuels," (FLEXnCONFU) is a research project funded by EU's research and innovation program Horizon2020. The goal is to develop and demonstrate economically viable and replicable Power-to-X-to-Power (P2X2P) solutions that convert renewable-sourced electricity into hydrogen or ammonia prior to converting it back to power. This will enable the design and operation of an integrated power plant layout that can untap additional combined cycle flexibility.

Alternative fuels such as H_2 and ammonia (NH_3) are part of a planned fuel switch in EU to reduce emissions. FLEXnCONFU will first be demonstrated in a microturbine. A consortium of 21 partners is led by Rina Consulting. It includes EDP Gestão da Produção de Energia, Centre for New Energy Technologies, Baker Hughes, MAS Advanced Technologies for Power and Energy, Hydrogenics (part of Cummins), Proton Ventures, Tirreno Power, Engie Laborelec, ICI Caldaie and academic and research institutions.

Capstone digest

Capstone Turbine distributor Cal Microturbine signed a long-term service contract for a 1 MW Capstone C1000 Signature Series microturbine system installed at a Wastewater Treatment Plant in Southern California. It provides 10-years of service coverage, including both scheduled and unscheduled maintenance. The plant uses microturbines on biosolid-based renewable fuel for electrical & thermal generation.

Capstone Turbine received an order for three C65 microturbines from for a large oil and gas midstream operator from distributor Lone Star Power. Commissioning is planned for this summer.

Capstone Turbine received an order to provide a 600 kW Signature Series microturbine to a pharmaceutical manufacturer in Mexico. Distributor DTC Solutions secured the order, which is scheduled to be commissioned in July 2020. The natural-gas-powered microturbine will be installed in a 90,000-square-foot facility and serve as a pilot project to show the benefits of microturbine technology in a CHP application, with the potential to implement the solution across two additional manufacturing facilities.

Capstone received an order for the Walker's Cay redevelopment project in the Caribbean that includes two C1000 Signature Series (C1000S) microturbine energy systems. Secured by E-Finity Distributed Generation, these units will be commissioned in the Fall of 2020. The liquified natural gas (LNG)-fueled C1000 Signature Series systems will replace diesel reciprocating engines.

Capstone received an order for a three-bay, 400 kilowatt, C400 Signature Series (C400S) microturbine system to modernize a water pollution facility in upstate New York. The microturbine will be utilized in a CHP application and will run on biogas produced on-site from municipal solid waste. Distributor GEM Energy secured the order. The CHP plant will incorporate new digesters, advanced gas treatment and heat exchangers for heating the digesters. The microturbine will generate electricity for the facility with recovered heat utilized to sustain the digester process.

Capstone has received an order for two microturbine skid packages from an oil and gas exploration and production company in the Sultanate of Oman. Pipeline Supply Company (PSC), Capstone's exclusive distributor in Oman and Qatar secured the order which is expected to be commissioned in the spring of 2021. Each skid will include two C65 Capstone microturbines. They will run on high pressure sour gas extracted from hydrocyclone systems at oil and gas processing stations. High pressure gas from the hydrocyclones at each site will be bled down, cleaned and conditioned before being used in each microturbine. The power generated will be fed back into the customer's low voltage power grid.

LNG struggles

Reduced demand due to economic slowdown, coupled with the Covid-19 outbreak, has led to cancellations of long-term LNG supply contracts and cargo deferments by importing counties. This has led to low utilization of liquefaction capacity, primarily in the U.S. Furthermore, the fall in gas prices deepens the crisis for LNG suppliers and upstream gas producing companies in the region, said analytics company GlobalData.

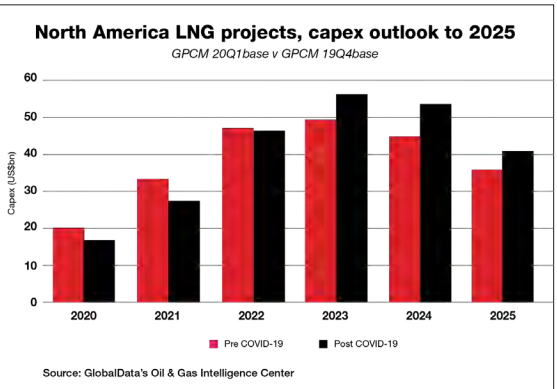
Failing to secure a long-term buyer commitment for its Driftwood project, Tellurian Investments is likely to delay its final investment decision (FID) by nearly two years. This is likely to push the project commencement timeline to 2025. Similarly, Pieridae Energy is delaying its FID on the Goldboro project which probably will not start now until 2025.

Royal Dutch Shell has also pulled out of the Lake Charles project, owned and operated by Energy Transfer. In the absence of a potential investor to replace Shell, the FID of the project may get delayed and its start year pushed back to 2027.

The Middle East and Africa (MENA) region, too, has experienced LNG supply contract cancellations and cargo deferments by importing countries. This has resulted in low liquefaction capacity utilization. The cascading impact of global LNG supply overhang coupled with reduced demand may lead companies to withhold or delay their capital spend on upcoming multi-billion-dollar gas projects, said GlobalData.

For example, the bidding process of Qatar Petroleum's Ras Laffan–North Field Expansion project means it probably won't start until 2021. Similarly, the Rovuma LNG project is likely to be delayed by a year.

Even active terminals are confronting challenges. The Egyptian LNG terminal has suspended its work till mid-July 2020 given current market conditions. And a deal fell through between ENI, Naturgy, the Egyptian government and EGAS to revive Damietta LNG terminal in Egypt.



Green LNG

Siemens Gas & Power has entered into an agreement with Total in green LNG production. As part of the contract, Siemens is exploring possible liquefaction and power generation plant designs, with the goal of decarbonizing the production of LNG. Target areas include reducing the environmental footprint of LNG liquefaction facilities and the associated greenhouse gas emissions, plant reliability, maintainability, regulatory compliance, and development costs. Gas turbine- and electric-driven compression trains are being considered in tandem with proven single-mixed refrigerant and double-mixed refrigerant technologies. The minimization of process flaring; heat recovery, inlet air chilling, supplementary firing, renewables integration and battery storage are also being considered, as well as how to leverage digitalization and automation platforms to optimize plant design.

Combined Cycle starts up

Alliant Energy's West Riverside Energy Center has started commercial operations. CCPP near the city of Beloit, Wisconsin incorporates a GE 7A.05 GT. The project team included AECOM serving as the EPC contractor, many subcontractors, as well as HDR contributing as the owner's engineer. The next step includes constructing a 6 MW solar facility adjacent to the natural gas generating station.

Flender in Australia

Flender, a supplier of mechanical drives and a subsidiary of Siemens, has announced plans for a new facility in Tonkin Highway Industrial Estate in Bayswater, Western Australia. It will target the wind energy and mining sectors. It includes a new purpose-built 3,500 square meter facility set for completion in September, and a 1.5 MW test bench capable of testing complete drive systems up to a voltage of 6.6KV.

LNG export tank

Venture Global LNG has announced the raising of the first LNG storage tank roof at the company's Calcasieu Pass LNG export facility in Cameron Parish, Louisiana. The 1.8 million pound tank dome and assembly were air raised into place, enabling the roof to be erected concurrently with the shell. CB&I Storage Tank Solutions, a division of McDermott International, is constructing the project's dual 200,000 m3 tanks. The facility's marine perimeter wall (including access road gates) and levee are also complete. Weeks Marine and EPC contractor Kiewit worked together to complete this scope. Piperack modules and equipment for the project's 720 MW CCPP has arrived and is being installed. The 10 MTPA facility is under construction at the intersection of the Calcasieu Ship Channel and the Gulf of Mexico.


The Venture Global Calcasieu Pass LNG Export Facility is under construction.

The new Baker Hughes LM9000 gas turbine is undergoing testing

LM9000

Baker Hughes has completed the First Engine to Test (FETT) on an LM9000 gas turbine that is to be deployed at the Arctic LNG-2 project. The test supports the OEM claims of 43% efficiency, 15 ppm NOx emissions and higher availability thanks to long maintenance intervals (12,000 hours for borescope, 36,000 for hot section replacement, 72,000 for overhaul).

Derived from the GE90-115B aircraft engine that has been used on Boeing 777s since 2004, the LM9000 has pressurized LNG compressor startup capability without helper motor assistance. Its modular package enables faster installation. For mechanical drive, it offers 67 MW, an exhaust temperature of 455°C and an exhaust flow of 184.5 kg/s at an output speed of 3,429 rpm.

PRECISION GEAR MANUFACTURING AND DESIGN ENGINEERING

See our Q&A on page 38

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START-UP & POST-COMMISSIONING

KEY CHALLENGES & CONSIDERATIONS FOR TURBOMACHINERY

BY AMIN ALMASI

Commissioning should be done in pre-planned stages. The first stage includes the operation of individual items of equipment and machinery for the first time. The pre-energizing checks include sequence checking and testing of the mechanical, electrical and control sub-systems to determine if each item is satisfactory and will function as required without problem or damage.

Following the satisfactory initial operation of individual sections of the turbomachinery package, they are integrated into the complete package. Sequential start-up, operation and shutdown of each system should be performed.

The next stage is the operation of these integrated systems. Once the loop test of each system is completed, each system is integrated into the turbomachinery package. That is followed by final commissioning of the integrated package and its upstream/downstream facilities. During this period up to the commencement of the start-up, all systems, integrated together as a single unit, should be checked and adjusted under various modes of operation and loading configurations. This includes verification of stable software programs, software configurations and the overall hardware setup. These should also be documented and archived for recordkeeping purposes.

Start-up

Start-up is the moment when the package is put in actual operation for the first time. During commissioning, operational procedures and instructions are prepared for start-up and operation. But following start-up and the initial weeks of operation, corrections are incorporated into an updated version of operational procedure.

During start-up, each unit is typically brought up to operating conditions (operating temperature, operating pressure, etc.) and held there for a period of time to validate the integrity of the unit before material or fluid is allowed to flow to the next downstream unit. Some equipment, for instance, may be able to safely work in bypass or recycle mode to validate the integrity of package.

Skilled operators and start-up specialists are needed during start-up to undertake initial operation.

Skilled operators and start-up specialists are needed during start-up to undertake initial operation. Should a problem develop such as the need for an emergency shutdown, it is important to have veterans on hand who know how to deal with it. These experts should continue to operate the package until everything is stable, at which point regular operators take over.

Post-Commissioning

Post-commissioning tasks cover a wide range of activities and actions after start-up to smooth out any issues that crop up during the initial weeks or months of operation. The reliability run is important, for example. It is a defined period, often one or two months, during which the turbomachinery package with all its items and auxiliaries operates under normal working conditions without major interruption or shutdown. Should a major shutdown or failure occur sufficient to prevent safe and full commercial use of the unit, the reliability run should be considered void. A reliability test of two or three month would then recommence after the contractor/vendor has remedied the cause of the defect.

For modern, controlled packages and facilities, failure to operate in accordance with normal operating procedures with all systems under automatic control might also be considered a failure in the reliability run. However, a minor intervention might not be a breach. Such defects typically do not require a shutdown and do not result in output reduction. Similarly, defective components and parts which do not lead to a shutdown might be considered only as minor defects. However, there have been different interpretations of such situations. However, even minor defects should be properly analysed and reported.

As the result of changes, modifications and corrections during the commissioning and start-up, a set of documents should be issued with all corrections and changes. This is usually known as the "as commissioned" set of documents.

Lastly, comprehensive training of the operations team is vital. They must review operational procedures, complete all necessary training and be up to speed on the latest documentation related to their equipment. ■

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.

Emerson Ovation control system

THE EVOLUTION OF TURBOMACHINERY CONTROLS

CONTROLS & INSTRUMENTATION PLAY CATCH UP WITH TECHNOLOGICAL INNOVATION

BY DREW ROBB

Turbomachinery controls and instrumentation have been relatively slow to evolve. But an unprecedented wave of technological innovation over the past decade is bringing about drastic change.

The Industrial Internet of Things (IIoT), digitalization, microprocessors, new software platforms, the cloud, advanced analytics, machine learning, wireless technology, mobility, connectivity, augmented reality, virtualization, artificial intelligence, cybersecurity, big data, Software-as-a-Service (SaaS) and many other breakthroughs have advanced the field like never before. The advantages include remote monitoring and operation, digital twins, remote field service, maintenance automation, real-time plant and fleet management, tighter inventory control, fewer unscheduled outages, and longer plant and equipment lifespans.

Companies like Compressor Controls Corp., Emerson Automation, Baker Hughes, Mitsubishi Hitachi Power Systems, GE Steam Power, Honeywell Process Solutions, Regal Beloit and Veros Systems are in the forefront of this trend. They are harnessing these technologies to make their control systems and instrumentation smarter, more responsive and more user friendly.

Tim Shea, Senior Analyst, ARC Advisory Group, predicts that there will be a period of sustained growth for turbomachinery controls over the next several years.

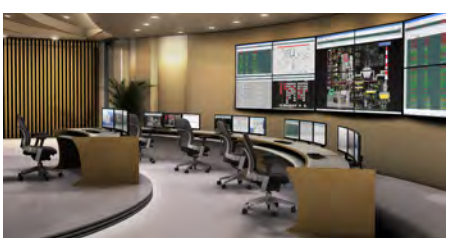
"This market has tremendous opportunities with steady growth driven by replacement of legacy turbine monitoring and controls with new features such as the growing demand for smart connected products based on the Industrial Internet of Things (IIoT)," said Shea. "The drive for process manufacturing productivity growth is pushing companies to invest in new turbine monitoring and controls for various process industries applications driven by trends such as digitalization and IIoT."

MHPS-Tomoni

A digitalization initiative from Mitsubishi Hitachi Power Systems (MHPS) is called MHPS-Tomoni This encompasses controls, instrumentation, data analytics, artificial intelligence (AI) and more. It is aimed at making power plants smarter. The average plant has nearly 10,000 sensors that can generate more than a million points of data every minute. MHPS-Tomoni takes this confusion of data and puts it into a useable form.

"Digitalization is becoming the norm," said Ron Thomas, Senior Manager, Control Systems Integration, Mitsubishi Hitachi Power Systems Americas. "It is crucial to understand what is happening within the turbines and entire plant as operators need to be able to analyze copious amounts of data in real time to detect correlations between different components to improve efficiency, reliability and flexibility."

MHPS-Tomoni is a suite of digital solutions that can help to create an increasingly smart power plant that will ultimately become capable of various levels of autonomous operation. Increased digitalization of interconnected devices and systems assists control systems to do more, and interface more effectively with advanced analytics. In parallel, steady advances in CPUs, memory and similar digital building blocks provide the opportunity to increase the capabilities of control systems, while boosting speed and cost-effectiveness.



MHPS control room

"We are focusing on the continued development of real-time adaptive control and actionable knowledge to optimize power plant performance and improve reliability," said Thomas. "These technologies hold great potential for making plants more productive, profitable and environmentally friendly."

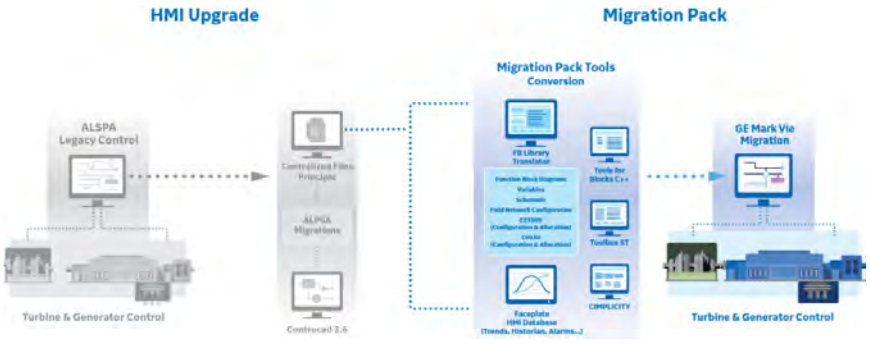
The IIoT, for example, offers increased availability of smart sensors and smart devices that can provide expanded data for more comprehensive control and protection strategies, as well as analytics that are derived from control system data. MHPS is investigating how to securely use IIoT sensor inputs for critical low latency control system inputs with jamming immunity.

Modern data management and connection protocols and platforms such as the OSISoft PI System have also proven useful in facilitating communication, data sharing and synergistic total plant control strategies among different control systems and programmable logic controllers (PLCs) in the power plant. Similarly, the steady evolution of computer operating systems adds new capabilities to control system software. This can create a challenge, though, in terms of keeping software updated and incorporating the latest security patches for effective cybersecurity.

The cloud, too, facilitates greater use of advanced analytics and machine learning to provide benefits to power plant operations & maintenance (O&M). Cloud-based analytics, diagnostics algorithms and artificial intelligence are providing more powerful computation capabilities. This offers the ability to make fleet-wide correlations that incorporate the operational experience of many similar power plants and support new concepts such as autonomous logistics systems.

All of these advances are taking place at a time when mobility and wireless functionality are facilitating new O&M support applications such as remote support using augmented reality (AR), auxiliary equipment monitoring and autonomous logistics systems to make operational support more productive. Additionally, virtualization has radically changed product lifecycle costs, removed hardware dependencies, and made it easier to provide cyber security and feature enhancements without costly hardware upgrades.

"Greater connectivity with smart devices in the plant and centralized analytics that perform monitoring, diagnostics and logistics management enable total plant O&M optimization strategies," said Thomas. "New approaches to O&M support such as remote combustion tuning, controls settings changes and remote balancing support offer a channel for expert advice and support to on-site staff."



Upgrades are available from legacy ALSPA controls to the GE Mark VIe control system.

He added that customers are asking about cybersecurity, life extension of existing control systems that are using older components and operating systems, virtualization, and automation of O&M workloads.

What has this meant specifically for MHPS users? The MHPS DIASYS Netmation (Digital Intelligent Automation SYStem) controls platform was initially introduced in the early 1980s. It has undergone several major upgrades as digital technologies advanced in the ensuing years. The latest version, Netmation 4S being introduced to combined cycle plants takes advantage of recent advances to increase operational reliability and reduce maintenance costs. It achieves this by leveraging machine learning, analytics and autonomous systems. The MHPS Virtualized Netmation and Netmation Protect Pack products provide cybersecurity protection and automation of most of the recurring update and maintenance activities related to keeping control system software current.

"The trend toward increased digitalization of power plants will only accelerate over the next several years to improve their flexibility and profitability, making them more intelligent using advanced analytics and cloud computing," said Thomas. "Plant control systems lie at the heart of the trend and provide the foundation for increased digitalization, connectivity and cybersecurity."

Further, control systems are advancing to keep pace with changing turbomachinery needs. For example, gas turbines are being developed to run on hydrogen and control systems will play a major role in enabling these new applications.

With MHPS launching the T-Point 2 validation power plant in Japan, the company is in the latest phase of autonomous plant development. Many MHPS-Tomoni digital solutions were validated at the original T-Point 1. T-Point 2 entered commercial operation with a Netmation 4S control system and more than 20 digital solutions that support increased autonomy of critical systems and soon the entire plant.

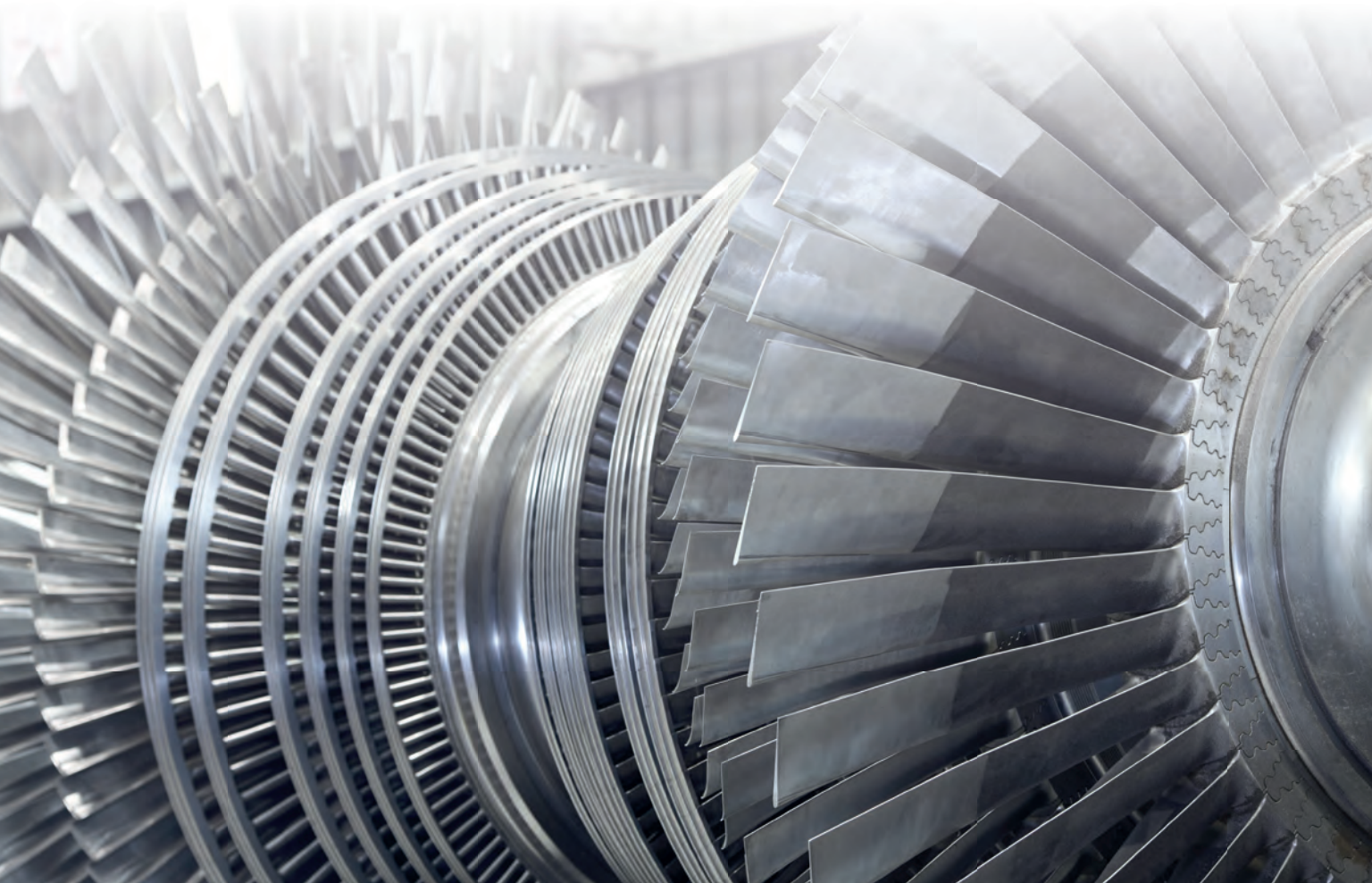
GE Steam Power

Olivier Jamart, GE Steam Power's Leader of Automation and Controls, said that current software and controls have changed dramatically from the original analog card versions that still exists in many industrial and nuclear power plants across the world. "The pressure on operating budget and on higher flexibility can be lessened by embracing the new software and controls," he said.

GE's Mark VIe control system offers a flexible platform for multiple applications. It features high-speed, networked I/O for simplex, dual, and triple redundant systems, and Ethernet for I/O, controllers, and supervisory interface to operator and maintenance stations and third-party systems. The GE Predix platform offers access to many digital apps and cybersecurity. Plant-wide applications such as Asset Performance Management use historical data and real-time data analysis to predict potential equipment failures and diagnose related issues to help reduce unplanned downtime and improve reliability. Asset-specific applications, such as Generator Health Monitoring, continuously monitor the rotor and stator conditions.

Jamart said GE offers upgrades to the latest industry standard with minimal disruption by easing the migration process. For example, the ALSPA installed base can be switched to the Mark VIe platform. This requires no modifications to I/O modules and related process wiring, reusing of electronic cabinets and automatic migration on the software application (control schemes and control libraries) to the new engineering workstation. The latest cybersecurity practices are incorporated.

"As operators embrace digital technologies to modernize their control and software assets, they are more vulnerable to cyberattacks," said Jamart. "GE Steam Power offers a proven cybersecurity solution on legacy and new operational technology (OT) to help power companies and utilities plan, design and implement operational resilience into people, processes and technology."



CCC's Guardian ODS controls

CCC

For Compressor Controls Corp. (CCC), software changes are mostly focused on cybersecurity, broader integration of high-speed machinery data and virtualization. Collaboration with SEEQ has made it possible to more easily analyze operating data to quantify the potential economic benefits that controls could have on turbomachinery and process performance. Open and standard programming methods have allowed the company to port our algorithms to other platforms in a manageable and supportable way. Broadened access to high-speed control data is also allowing users to do better analysis of data. A new high-speed data historization algorithm allows CCC to send data to the historian while minimizing bandwidth, storage, and loss of data due to data compression.

Cybersecurity and Distributed Control System (DCS) support are the two technologies most mentioned by CCC customers.

"Cloud and wireless have had little impact on our offerings to customers," said Richard Hall, Vice President of Product Management & Marketing at CCC. "IIoT is something we are watching, but we haven't had a strong signal from customers during our Advisory Board meetings that it's something they see as a priority."

CCC's Prodigy system is growing well, mostly driven by reliability and control capability. CCC control applications such as Antisurge, Performance, Master/Loadsharing, Speed/Extraction, Fuel and others are at the core of its offerings. But the company has been developing new technology. Process Optimization Studies, Security Update Management, and Guardian Pro ODS (Overspeed Detection System), address areas such as the use of data analytics, improved cybersecurity, and expanding control capabilities to other platforms.

Hall expects market segmentation to continue. Some want automation standardization while others want better performance and security. His company's approach is to offer solutions for either customer type. For those that want great performance and a focused experience, hardware based solutions are available. For those that want good performance and alignment with broader automation systems, CCC systems are available.

In the aftermarket, users are suffering due to downsizing and retirements. They need support from vendors with long-term turbomachinery experience. As a result, CCC is signing more service and support contracts, as well as doing more retrofits and replacement of controls from other providers.

"The controls that get put in during a project may not be supported by the small companies that specialize in the algorithms, or the mega-firms that focus on large-scale automation systems," said Hall.

Emerson

Emerson designed its Ovation platform to be able to evolve to take advantage of the latest technologies. This includes analytics, digital twins, mobile and remote work, and cloud-based services. All are embedded in the Ovation automation and software platform. Wireless technology, cloud storage, and mobile devices transmit data from the process and asset level and make it available to the operator, maintenance engineer or plant manager wherever they may be located.

Emerson analytical solutions go beyond basic diagnostics to identify impending process upsets or equipment anomalies and trigger mitigating action to avoid downtime or damage. This is accomplished via modeling, AI based on advanced pattern recognition (APR) and machine learning. Ovation also supports integrated vibration monitoring, generator excitation control, safety instrumented systems, distributed applications, virtualization and digital twin embedded simulation. Subscription services for Ovation include cloud-hosted digital twin and engineering services to supplement onsite resources and reduce the maintenance burden. Cybersecurity features help to bridge the gap between operational technology (OT) and information technology (IT) to mitigate risk.

"Our customers are seeking to digitally transform their operations and our focus is on using technologies and services to accelerate their efforts," said Jason Blackburn, Director Global Power Marketing, Emerson's Power and Water Solutions. "There are operational performance and financial results to be gained by leveraging IIoT data across platforms from wireless and other sensors to control systems to asset performance platforms and making this data available across the enterprise."

He noted that customers are asking how they can keep their plants running safely, even when there are fewer personnel onsite due to limited travel and site-level access. With mobile applications, they can remotely monitor control systems and processes offsite. The Ovation Machinery Health Monitor also provides alerts and insights for operators and maintenance technicians on the health and performance of rotating machinery. Vibration events can develop slowly over time and escalate to failure with little warning.

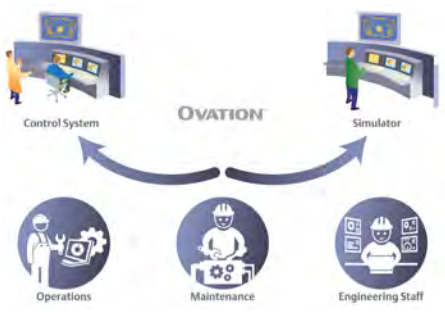
Blackburn believes that the industry will continue to leverage IIoT technologies, edge computing, AI, machine learning, analytics and expert system technologies. By expanding their digital footprint, users can transition toward semi-autonomous operation.

By installing Emerson's Ovation technology at its Redbud combined-cycle power plant, Oklahoma Gas and Electric (OG&E) gained the ability to cold start each unit 25 to 35 minutes faster. Located in Luther, Oklahoma, the Redbud plant comprises four identical 1 X 1 units generating a combined output of 1,230 megawatts. The plant began commercial operation in 2003 outfitted with controls from nine different vendors. This patchwork of control systems presented numerous challenges.

"We recognized the inefficiencies inherent in utilizing multiple different control systems. We wanted to consolidate to a standard automation platform to improve reliability and consistency across all units," said OG&E's Khoa Le, project manager for the controls upgrade.

Emerson replaced the steam turbine controls as well as static excitation and vibration monitoring systems with an integrated Ovation solution. In addition, Emerson performed steam turbine mechanical retrofits to eliminate single points of failure and provide faster response. With the upgraded and tuned steam turbine controls, along with the redundant mechanical design, the turbines can reach setpoint quicker, reducing cold start times by 25-35 minutes per unit.

Emerson also replaced heat recovery steam generator and balance-of-plant controls at each unit and integrated the auxiliary boiler, water treatment, effluent de-ionization and duct burner controls into the Ovation system. Tied together on



Schematic of the scope of Emerson Ovation controls

a single network, each unit's Ovation system interfaces with OEM combustion turbine controls for supervisory monitoring and control.

Previously, plant personnel had to monitor multiple process and alarm screens from different vendors. By paring down thousands of control sheets to hundreds and implementing consistent logic, graphics and alarm philosophies across the entire plant, greater visibility was gained into plant processes. Work for all four units was completed during a 16-week outage.

Honeywell Process Solutions

Industrial process automation is an early form of IIoT that has been in existence for many decades. Control systems at large process plants connect thousands of measurement devices, equipment, and valves. Communications with these devices happens in a coordinated way using control methods to operate a complex process in a way that is safe, reliable and efficient.

"We are scratching the surface in helping users achieve better performance during operations," said Jason Urso, Vice President & CTO, Honeywell Process Solutions. "With more pervasive sensing, new sensor types, faster data collection, and new analytics methods, we will see an inflection point where technology can help users achieve greater performance."

He considers digital transformation to be invaluable in areas such as converting data to knowledge and knowledge to action. Project execution, for example, typically involves sending large numbers of people to remote locations and working on the physical equipment until a project is complete. By representing the physical equipment as a digital twin, project engineers can work remotely and on a virtual version of equipment. This has been implemented at Honeywell to complete the development of controls, displays, and safety logic, as well as subsequent testing of those systems.

That same digital twin technology can also be used for the training of operations staff. Further, it can be used to monitor process and equipment reliability. With a digital representation of a process and equipment, actual performance can be compared against optimal performance represented by the digital twin.

The cloud is another area of innovation. Honeywell Forge Enterprise Performance Management (Forge) is a software platform that includes applications tailored to improving throughput, yield, reliability and efficiency. It can operate in the cloud and on premise. Those selecting the cloud, receive the set of application capabilities without needing to maintain the software or underlying hardware platforms.

In light of the current crisis, many customers are seeking solutions that allow them to work remotely. Remote operations, remote service, and remote project engineering methods have become essential to maintain business continuity in an environment where the number of personnel onsite must be minimized. Honeywell has evolved its offerings to support these new methods of remote work. Experion PKS Augmented Remote Operations software is a new Honeywell offering that allows process operators to both monitor and control a process from remote locations. An example of this would be a case where a local control operations center must reduce staffing to comply with HSE or local government requirements associated with social distancing. Experion PKS remote operations can quickly and securely establish a remote operations center in an alternate facility either onsite or remote to the site.

"Technologies like digital twins, remote operations, virtualization and wireless are a means to assure every day is the best day of production and every person is an expert," said Urso.

Further products include:

• Honeywell Forge Enterprise Process Management that combines applications with digital twin technology to achieve better levels of throughput, yield, reliability and efficiency.

• Experion PKS Augmented Remote Operations to extend operations to remote locations.

• Experion PKS HIVE (highly integrated virtual environment) – using Honeywell LEAP project execution principles, software and networking to unchain control applications from physical equipment, and controllers from physical IO.

As for the aftermarket, there is a need to address the many aging controls deployed in the 1980's and 1990's. Part obsolescence presents a lifecycle management challenge. Replacing the legacy system can be time consuming and expensive as the built-in intellectual property (IP) has to be recreated. Honeywell's ELCN offering utilizes virtualization to evolve legacy technology without the need for IP recreation. It does this by taking the legacy hardware and emulating it in software. This enables users to operate existing controls as-is within a software environment. The old hardware is eliminated.

Baker Hughes

The Internet of Things has forced many to take another look at the way users want to operate their turbomachinery units. They are no longer looking to only access data and view data aggregation such as historians. Instead, they are demanding outcomes or recommendations to improve operations. This trend led Baker Hughes to evolve the Nexus OnCore Control System to support edge devices including IIoT. This provides a means of conducting more in-depth analysis as well as remote monitoring for those that want to consolidate expertise in different locations. The Nexus OnCore Control System can integrate with many wireless technologies. It can also support secure remote management, as well as, a Managed Services offering to securely support remote working (work from home) environments and situations.

In addition, the Nexus OnCore platform has a simplified Human Machine Interface (HMI) to make it more intuitive and easier to operate by younger, lesser experienced staff. This helps them to learn the product rapidly and become productive in less time than would be possible using older generation control systems.

Terry Knight, Vice President for Control & Safety Systems at Nexus Controls, Digital Solutions of Baker Hughes, believes that we are not yet in a position where control of equipment can or will be directly from the cloud. However, he said some are becoming more comfortable with sharing information to an external server via their own intranet, or to the cloud. This

The NexusOnCore control system from Baker Hughes

Plant operator using Regal Beloit controls to interact with a condition monitoring system using augmented reality

is especially the case if they have multiple plants in multiple locations to enable them to conduct fleet analytics, for example.

Over the years, he's witnessed many stages of evolution in controls. It began with mechanical to electrical/electronic drives, then moved from analog to digital technology. Over time, digital technology has become more compact, more reliable and faster.

"The next phase will be with us for some time as we figure out what should remain a typical control system, what can change to edge computing, what can be conducted in a cloud environment, what do we do with all the data available to us to drive outcomes, whether to transmit to the cloud and conduct analytics there, or conduct more analytics at the sensor level," said Knight.

Regal Beloit

The IIoT megatrend has created more need to efficiently integrate technologies and data sources into one place, while allowing access to different users, said Dan Phillips, Technical Director, Regal Beloit America. His company has been integrating IIoT into its controls, new application technologies to leverage pattern recognition techniques, the cloud for secure remote monitoring, and wireless connectivity.

"One challenge that we see frequently with wireless technologies is that sensors may not be applied correctly to the asset and do not provide advanced warning of faults or degradation," said Phillips.

The company is also utilizing augmented reality to instruct and train personnel on the assembly and repair of electromechanical systems. It allows users to look at equipment on a tablet or smartphone to monitor equipment conditions. They can peel back equipment layers to look at critical components, read bills of materials and gain a better understanding.

Phillips does not believe in one-size-fits-all systems. Every scenario is a little different. Prior to deploying a technical solution at a customer site, it is important to spend time identifying the value proposition and understanding how success is measured as each asset may have a different critical component. In some applications, the gearbox might be the most critical. In others, it may be the motor, a bearing, or multiple gearboxes or motors.

"Having a scalable system allows for the flexibility to monitor all the components within an asset," said Phillips. "Additionally, a scalable system allows a user to expand the system to adjacent power transmission applications instead of having to invest in different technology."

Veros Systems

Veros Systems (Austin, TX) is a startup with backing from Shell Ventures and Chevron Technology Ventures. Veros uses data-processing techniques to decipher the current and voltage waveforms associated with motors to gain insight into the performance, mechanical and electrical condition, and likelihood of failure of rotating equipment. Electrical waveform data are sampled at the existing distribution infrastructure (i.e. VFDs, starters, breakers).

"We collect and analyze just under 400,000 data points each second per motor and only use electrical signals in our analyses," said Jim Dechman, President & CEO of Veros Systems. "We utilize an edge device in the electrical cabinet to sample, digitize and compress the electrical waveforms that feed a motor. This data is sent to the cloud for machine learning."

This allows a motor to communicate its condition, the condition of the machine it is driving (compressor, pump, fan) and the overall performance of the drivetrain. Tapping into the electrical waveform signals is non-intrusive and fast. Installation of external sensors (such as accelerometers and proximity probes) and associated cabling is not required.

A massive dataset has been accumulated with readings that show how a motor performs over time. Should the waveform readings deviate from the accumulated dataset, alerts are transmitted. With more than 50 million large motors in factories and plants around the world consuming about half the world's electricity, Veros provides a means of tapping into their electrical power lines to detect impending issues or failures. The company has licensing or distribution relationships in place with Fluke and Siemens with more in the pipeline wanting to integrate these measurements into electrical power distribution systems and devices.

"Tapping into an electrical conductor and providing warnings a month before a compressor fails helps the operator to conduct repairs or schedule replacement of the machine," said Dechman. "Veros can also analyze the motion of the motor's rotor to show how effectively it is operating."

The technology achieves this by creating a model of motor health. It tracks the motion of the motor rotor for any developing mechanical issues are developing. Flutters in rotor movement are transmitted through the air gap and can be detected in the electrical waveforms. A bearing issue in a compressor, for example, exchanges energy that impacts the rotor. Machine learning is used to filter out process variations, electrical line variations and other noise. ■

Jim Dechman, Veros Systems

WEATHERING THE COVID-19 STORM

STRATEGIES INCLUDE DIVERSIFICATION, LIQUIDITY, AND MAINTAINING CONTACT WITH CUSTOMERS

BY RORY PASQUARIELLO

No one saw a Covid-19 pandemic coming. Big changes were made virtually overnight. Most in the sector report decreased sales, project delays, supply chain disruption and warehouse shortages. The pandemic is expected to reduce power consumption in U.S. commercial and industrial sectors by more than 4%, according to GlobalData.

Yet there are encouraging signs. Oil prices have rebounded somewhat, and infrastructure projects are restarting as economies cautiously reopen. For example, GE completed its first major onsite inspection project since the Covid-19 outbreak in China.

Turbomachinery International interviewed turbomachinery industry leaders to see how they're faring, what's changed, and how they are responding. Companies such as Mitsubishi Hitachi Power Systems, Howden, Rotoflow, SSS Clutch, Velo3D, Sullair, Voith, MTU Power and PAL Turbine Services reported on how they are adjusting to social distancing and other guidelines. Some of them said they are pivoting from onsite work to remote maintenance services. Others are investing in new technologies such as digitalization and the Internet of Things (IoT) or providing employees with better training. More than a few have stripped down their operations to focus on core competencies.

Howden

Howden, a manufacturer of compressors, steam turbines, heaters, fans, and blowers, noted postponements and cancellations of planned outages with subsequent cancellation of spare part orders. That's hit their bottom line.

In response, Howden expedited the launch of a new remote service that uses an augmented reality annotation technology with real-time communications based on the Chalk app from PTC. It connects remote product experts to on-site field technicians and customers. The company also hired a dedicated IoT Strategy Manager to improve its digital solutions.

"We see opportunities in remote monitoring and support; as well as customer self-service interface points as key elements of a post-Covid world," said Darryl Halter, Vice President, Aftermarket at Howden. "As customers continue to place requests for quotes, we see that as a good indication that they are looking to proceed with projects when this is over."

Halter's advice? Adapt and innovate. "When situations like this arise, we are leaning into it, not fighting it. Accept that this is the reality. Adapt to it and innovate in ways that benefit the customer and the company."

Sullair

Sullair, an Indiana-based manufacturer of portable and stationary rotary screw air compressors (a subsidiary of Hitachi), has felt Covid's impact, particularly in its operations and facilities in China. It is continuing to focus on its core business. With no trade shows on the horizon, it is stepping up efforts along other marketing channels.

"We are actively looking at other means we can communicate our message including virtual events," said Brian Tylisz, Vice President, Americas, Commercial & Industrial at Sullair.

After mandated shutdowns ended, Sullair reopened its factories and ramped up business. But when business-as-usual will return is anybody's guess.

"Nobody within our industry had this in their business plans for 2020," said Tylisz. "With nearly six months to go in the year, it is difficult to predict a full-year impact."

While thankful for tools that make it easier to communicate digitally, he said that nothing can replace face-to-face interaction.

"There is nothing like sitting down, having a meal and looking somebody in the eye while talking business," said Tylisz.

MHPS

Despite Covid, business at Mitsubishi Hitachi Power Systems (MHPS) is doing well. The company had a record year, and ranked first in market share by megawatts for gas turbine orders in the first quarter of 2020. The MHPS remote monitoring and diagnostics centers have helped the company leverage real-time data to help users make risk-informed decisions on delaying planned maintenance safely.

"Right now, it's all about flexibility and ensuring that our customers are able to reliably keep the lights on while so many other factors in our lives remain

Sullair centrifugal installation

unknown," said Marco Sanchez, Vice President and Head of Intelligent Solutions at MHPS Americas.

The current crisis has made it clear that plant operators need remote operating solutions to improve operations and protect employees. As a result, MHPS is focusing even more on its Tomoni Autonomous Power Plant initiative.

"Going forward, we expect many inspection and maintenance tasks will be supported from an offsite location instead of in person," said Sanchez. Both artificial intelligence (AI) and machine learning will allow the knowledge of today's experts to be captured for the future."

Sanchez's advice to others in the turbomachinery sector? Have flexible contingency options in case of future disruptions. This should include cyber-secure communication channels with sufficient bandwidth for the desired level of implementation.

SSS Clutch

SSS Clutch, a Delaware-based manufacturer of automatic overrunning clutches for high-power and high-speed applications, was remodeling its UK facility when the world went into lockdown. It paused construction for six weeks, delayed employees from moving in and instituted remote work.

"Things were far from perfect and seamless, but there has not been a huge disruption," said Morgan Hendry, President, SSS Clutch. "The situation has helped us to establish better workflows and practices for the future. It prompted us to make positive changes."

SSS Clutch obtains about a quarter of its business from marine propulsion, a quarter from mid-stream and down-stream oil and gas and from half power generation. Hendry said the company hasn't skipped a beat on the operations side.

"We expect bumps in the road but not a fall off," he said. "There will be some delays and cancellations within our oil & gas portfolio, but we believe our overall business will not see a material effect."

Rotoflow

Rotoflow, a manufacturer of companders and expanders, has been operating at full capacity. It implemented heightened safety procedures for those allowed to remain at work in its manufacturing facilities. Office employees worked from home.

The effect of the crisis on the company for 2020 overall is uncertain. But one good sign is that it recently achieved record production in the industrial gases space.

"Once the crisis is over, we are looking forward to re-engaging with customers face- to- face, offering even more value-added solutions, and introducing new products," said Sarah Farnand, Rotoflow's Global Sales Manager, New Equipment. "One potential opportunity from the pandemic has been time to spend on some of our product development initiatives."

Her advice to the turbomachinery world: "Focus on what you can control, keep your employees safe, and don't let your guard down."

MTU Power

For MTU, which offers diesel and gas power generation system services, protecting customers from disruptions has been top priority. It temporarily scaled back to emergency staffing levels at its Berlin facility where GE LM series turbines are serviced. As well as protecting employees, this was a result of supply chain disruptions. With reduced staffing, the company maintained minimum service levels, carried out field services and received delivered engines and parts. This minimized disruption for customers.

"We intend to flexibly adjust shop capacities to meet demand going forward as we monitor the supply chain situation, COVID-19 developments and regional trends daily," said Gregor Stoecker, Director of Sales, Industrial Gas Turbines at MTU Power. "We can also support the ramp-up operations of our customers by offering intelligent repair solutions, flexible lease and rotable services, and sourcing of serviceable material."

Voith Turbo

The German-based Voith Group, which manufactures drive components and systems for turbomachinery, has weathered the crisis relatively well. It has carefully monitored its supply chain to keep it up and running. A few suppliers from regions like Italy and India struggled. But overall, its supply chain is almost back to normal.

That said, some large capital expenditure projects, especially in the Middle East, have been postponed. Further, travel restrictions have caused challenges in the aftermarket, especially in Europe and the U.S.

"Thanks to our global service footprint, we benefit from close customer proximity and the situation in China improved much earlier than in many other areas, so China strongly supported our business in the past weeks," said Rolf Schweizer, Executive Vice President & CEO Voith Turbo.

The drop in oil and gas prices hit Voith particularly hard. It specializes in drives for electrically driven gas compression for up-, mid-, and downstream applications. In response, it is strengthening its capabilities in the retrofit area.

In the short-term, Voith sees potential in service and aftermarket businesses.

"We will continue to invest in new products and solutions (such as VoreconNX variable speed drives, the VECO-Drive VFD, AeroMaXX turbo gear technology or new condition monitoring solutions) that provide competitive advantage," said Schweizer. "The current crisis has uncovered significant potential for digital collaboration, autonomous operation and remote maintenance."

Velo3D

Only a few months ago, Velo3D, a metal additive manufacturing (AM a.k.a 3D printing) solutions provider, AM applications in aviation and oil and gas were still vital sales targets. However, all signs point to those sectors scaling back capital expenditure investments. Sales at Velo3D initially declined 30%, forcing it to scale back operating and capital expenditures. It is now concentrating on its new product development pipeline. But the company

Rotoflow's Houston Service Center.

Cross-section of a CO_2 pump inducer produced using 3D metal printing by Velo3D. Photo credit: Barber-Nichols

also landed a $20M order from an existing aerospace customer and it hopes to be profitable again by mid-2022."As a smaller business, we are more agile and can shift our focus a little more easily than larger, publicly listed companies," said Benny Buller, founder and CEO of Velo3D. "We are targeting other industrial segments like aerospace, defense and energy. We are also putting more investment into marketing and business development."

One potential opportunity is in printing parts traditionally manufactured via casting. 3D printing offers much shorter lead times and lower cost for small quantities. Buller's advice to others in the turbomachinery sector is to stay agile.

"Agility is your strongest asset," said Buller. "Make investments in technologies that will enable you to be flexible to keep costs down and respond to customer and market needs quickly."

PAL Turbine Services

PAL Turbine Services, a subsidiary of Pond and Lucier, a field engineering services company focusing on legacy gas and steam turbines, is an example of the unforgiving nature of market disruption. The company has virtually ground to a halt with purchase orders drying up, according to Dave Lucier, owner and general manager.

He complained about public utilities and many private owners of gas turbines (refineries, process plants) looking with fondness at the lowest bid instead of insisting on experience and technical capability. As a result, PAL's 20 full and part-time engineers (each forty-year plus veterans) don't have much work.

"Clients don't want us to retire, but they won't send us business until they are in trouble," said Lucier. "Even then, they want us to accept reduced rates, though we charge about half OEM rates." ■

14 MW Atlas Copco expander turbine generator in an ORC plant

LNG REGASIFICATION

NEW CONCEPT FOR POWER INTEGRATION WITH LNG

BY JIM BERRY

The cold available at an LNG import regasification terminal is a resource that can be harnessed to produce cheap electric power. At most terminals, this resource is wasted. At the few sites that attempt to utilize it, the full potential to produce low cost power at minimum investment is not met. Utilizing this cold for inlet air cooling of the gas turbine of a combined cycle plant results in a power increase of only about 20% and a minor fuel rate improvement. For the same gas turbine applied to the new LNG Regasification Re-Condensing Power Cycle, the power increase is nearly 40% with a 15% decrease in the fuel rate. This cycle does not use steam, thus eliminating the problems associated with water treatment, condenser air leaks, deaerators and air ejectors corrosion. In addition, it has a small footprint and low dollar per MW cost.

Regasification processes

At most LNG import terminals, atmospheric pressure LNG is converted from a minus 260°F liquid to gas at pipeline pressure by first pumping cold LNG to high pressure. The cold, high-pressure liquid is then heated in a sea water heat exchanger to produce high-pressure natural gas, which is directed to the receiving pipeline. Most of the time, the available cold in the LNG is wasted by cooling sea water.

A few installations have incorporated processes that can use the cold such as a co-located air liquefaction plant. Other sites have integrated the gasification process with power generation, using some of this resource for gas turbine inlet air cooling in a combined cycle power plant to boost power output.

At a small number of facilities, LNG is pumped 500 to 1000 psi higher than the receiving pipeline pressure. It is heated with both sea water and a high-temperature heat source such as the exhaust from a gas turbine. The high-temperature, high-pressure natural gas stream is then expanded through a radial inflow turbine to produce power. The turbine discharge is directed to the receiving pipeline. This process has been combined with gas turbine inlet air cooling. Various Organic Rankine Cycle (ORC) cycles have been proposed for power generation integration with LNG regasification.

OnPower has devised a more efficient alternative. Its Re-Condensing Power Cycle is as follows: the LNG is pumped to a high pressure, heated and expanded to produce power. The LNG is first pumped to about 1500 to 2000 psi, heated in the vaporizing side of a vaporizing/condensing heat exchanger, superheated with gas turbine exhaust, expanded in a turbine to produce power, and then re-condensed back to LNG at a pressure of about 520 psi and -130°F in the condensing side of the heat exchanger. At that point, the 520 psi/-130°F LNG is pumped 500 to 1000 psi higher than pipeline pressure, heated, and expanded through a second radial inflow turbine to make additional power, with the discharge of the turbine directed to the pipeline. The cold in the -130°F stream can be used to make additional power via ORC. Residual cold from the ORC can also be used for gas turbine inlet air cooling. The radial inflow turbines involved in these processes can be combined on a single gearbox driving a single generator (See sidebar for a detailed explanation).

The results from this cycle are as follows; The fuel rate falls to between 4,500 to 5,500 BTU/KW-HR depending on the size and characteristics of the gas turbine, system design and other parameters; the power per mass of gasified LNG is more than 1000 kW per Kg/sec; sea cooling is reduced by up to 90%; as no steam is involved, there are no associated problems related to water treatment, corrosion or vacuum leaks; and the equipment has a smaller footprint compared to an equivalent combined cycle plant.

In addition to LNG import terminals, the system can be installed at large peak shaving LNG plants. Most of such plants operate for only a few hundred hours per year. When combined with the Re-Condensing Power Cycle, however, they can perhaps be utilized for thousands of hours per year. To do so, they would store gas as LNG at night using off-peak power and

Re-Gasification Power Cycle Performance

Application	Fluid	Mass Flow (kg/s)	Site Elevation	Net Output (kW)	Energy to Produce the Fluid (kW-hr)	Fuel Rate (BTU/kW-hr)	Power Per Mass Flow (kW/kg/s)	With ORC
LNG IMPORT TERMINAL	LNG	80.1	SEA LEVEL	101,340	N/A	5225	1265	YES
LNG IMPORT TERMINAL	LNG	117	SEA LEVEL	104,450	N/A	5068	874	NO
LARGE PEAK SHAVING LNG ENERGY STORAGE PLANT	LNG	78.9	400'	99,876	79,540	5295	1248	YES
LIQUID AIR ENERGY STORAGE	LIQUID AIR	85.5	400'	120,540	123,100	4330	1410	YES

Note: Estimated performance at 80°F using one (1) Siemens SGT-800 Gas Turbine; Inlet and exhaust losses accounted for

return it to the pipeline during the day while producing on-peak electric power.

In the Northeastern U.S., environmental concerns have restricted the building of sufficient pipelines to satisfy gas demand. A large peak-shaving LNG plant could reduce the need for new pipelines while providing peaking power.

Over-supply of natural gas makes it likely that natural gas and LNG prices will remain low for some time to come. This presents another potential application. LNG export terminals located in areas of high peak electric rates, using a portion of the produced LNG, could cheaply produce on-peak power as a revenue stream.

While this is a new process, the turbomachinery, heat exchangers and cryogenic pumps are well within proven manufacturing capabilities. Primary heat would typically come from gas turbine exhaust. However, it could also come from a gas engine. If ORC is added to the cycle, it can be sized to allow a second identical gas turbine to supply exhaust heat. Alternatively, the exhaust flow from a single gas turbine could be split between the LNG power cycle and ORC. There would be enough residual cold from the ORC to chill the inlet air of the gas turbine(s). Adding ORC to the Re-Condensing Power Cycle almost doubles power output with a nominal impact on fuel rate.

Two different temperature heat sources can be harnessed as part of this cycle such as the exhaust of a gas engine, and the jacket cooling water/turbocharger intercooler heat. With an intercooled gas turbine such as the GE LMS100, it is possible to use the exhaust heat and the compressor intercooling heat of the turbine.

Energy storage

Sites with cheap off-peak electric power could utilize hot heat transfer fluid heated as the second heat source using electrical resistance heaters. Power could be stored for use at peak times.

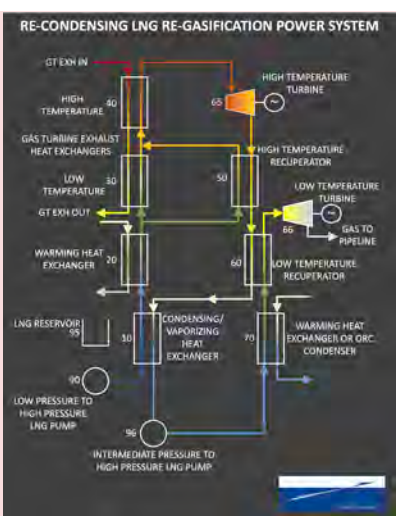
Another potential storage opportunity concerns the use of liquid air as the initial cold liquid as part of a liquid air energy storage system. In this application, the second pumped, heated and gasified liquid air stream is expanded through a turbine all the way down to atmospheric pressure. Alternatively, a portion of the heated and gasified air can be directed to a gas turbine combustor to substantially increase the gas turbine power. The remaining portion can be expanded through a turbine to atmospheric pressure.

The following manufacturers are thanked for their support with equipment selections and performance data: Chart Industries (cryogenic heat exchangers), Atlas Copco Gas and Process (radial inflow expander turbines); Siemens Energy (gas turbine performance), Tulsa Heaters (gas turbine exhaust gas heat exchangers) and Nikkiso Cryo (cryogenic pumps).

Jim Berry is Technical Consultant at OnPower, a packager of turbomachinery, a designer and builder of control panels, and service provider for gas turbine generator sets. In addition to 200 gas turbine generator sets, OnPower's experience encompasses supercritical CO_2, solid oxide fuel cells, gas turbine packages for patrol boats, rocket fin coatings and generator sets to support fracking operations. For more information on OnPower's patent pending Re-Condensing Power Cycle, visit onpower.com

How the Re-Condensing Power Cycle works

- Atmospheric pressure LNG in reservoir 95 is pumped to about 1500 to 2000 PSI in pump 90
- The LNG is gasified in vaporizing/condensing heat exchanger 10, then heated in heat exchangers 20, 30, 50, and 40 to about 550°F.
- The heated high pressure gas produces power in turbine 65 as the fluid expands to a pressure of about 530 psi.
- The gas then flows through recuperator heat exchangers 50 and 60, returning heat to the cycle.
- The gas is directed to the condensing side of vaporizing/condensing heat exchanger 10 and re-condensed to an intermediate pressure LNG stream (about 520 psia/-130°F) against the cold upcoming high pressure LNG stream.
- The intermediate pressure LNG is pumped to 1500 to 2000 psi in pump 96 and heated and gasified in ORC condenser 70 and recuperator 60.
- The heated gasified stream is directed to turbine 66 where power is generated as the gas expands down to the receiving gas pipeline pressure.



Peak load LMS100 gas turbine generators at LADWP include SSS clutches to switch operation from power generation to synchronous condensing for reactive power, spinning reserve and grid support.

NEW AND AGING TURBINES

HOW TO TURN OLD TURBINE GENERATORS INTO SYNCHRONOUS CONDENSERS

BY MORGAN HENDRY

The viability of peaking gas turbines (GTs) is under threat, especially in parts of the U.S and Europe where renewable power generation penetration is high. Due to prioritization of wind and solar, some utilities in California have power generation units running at a few percent capacity per year.

In extreme cases, this has led to closures. The 750 MW Inland Empire Energy Center in Southern California is being demolished despite being little more than ten years old. It's H-class GTs have been operating well below capacity for many years. The combined cycle site is going to be repurposed to become a battery storage facility.

These examples illustrate the economic dilemma faced by operators in some regions. The peaking and standby power markets are steadily dwindling as renewable energy plants multiply and battery storage is incentivized.

But closure of these plants is not only expensive; it may be short-sighted. Remove too many GTs and steam turbines (STs) from the grid and you are likely to cause disruption. Power quality will drop, and a lack of inertia could lead to instability and potential blackouts.

A better alternative may be to retain these plants and repurpose the generators of their idle turbines as synchronous condensers that can offer grid stability and other ancillary services. Then, if power generation is required in future, the plant can be restarted/recommissioned for generation.

This has been done successfully in scores of countries around the world. In North America, in particular, there are a large number of turbines operating as synchronous condensers. Los Angeles Department of Water and Power (LADWP) has four GE LMS100's operating primarily as synchronous condensers but poised to provide generation when necessary. Another four clutched LM6000 gas turbine generators operate at Commonwealth Chesapeake Power in Virginia. Further examples include: a clutched LMS100 at Calpine's Cumberland Energy Center in New Jersey; a PWPS Twin Pac with two FT-4s and clutches operating at Great River Energy, St. Bonifacius Plant near Minneapolis, Minnesota; and Sask Power's Ermine plant uses two clutched LM6000s to provide both real and reactive power to the Saskatchewan grid.

Numerous steam turbine generators, too, have been repurposed as synchronous condensers including: a 44 MW ST generator at City Electric Systems, Key West, Florida; four 150 MW generators at BC Hydro's Burrard Thermal near Vancouver, British Columbia, Canada; two 1150 MW ST generators at Zion Energy Center, Zion, Illinois, a 550 MW generator at NIPSCO's Baily Plant, Chesterton, Indiana; and two

Sask Power Ermine plant uses two clutched LM6000s to provide both real and reactive power to the Saskatchewan grid.

500 MW generators at Xcel Energy's Tolk Power Station in Texas.

Grid inertia

It is important to appreciate why such conversions should be done and how to go about it. Generators and motors provide inertia as they rotate at the same frequency as the electricity grid. Thus, the presence of GTs and STs acts as a buffer against power spikes and changes in frequency.

During the evening peak, frequency falls as people turn on air conditioning, heating, lighting and appliances. At off-peak periods, frequency drops and voltage rises as there is an abundance of supply. A constant balancing act goes on behind the scenes as system operators work to maintain voltage and frequency in the correct range (60 Hz for the U.S). Occasionally, utilities may have to disconnect neighborhoods from the grid to avoid damaging equipment and keep the rest of the network in operation. This is known as load shedding. Taken to extremes, a cascading series of outages can lead to a major blackout. The Northeast U.S. experienced this in 2003 when 60 million people were left without power. On a smaller scale, New York City and London suffered from blackouts during 2019.

The problems of inertia and grid frequency have been exacerbated as wind and solar replace more and more traditional energy sources. Wind doesn't provide inertia as frequency converters placed between the wind turbine and the electricity grid prevent the kinetic energy of their rotating mass from providing inertia.

Further, getting wind and solar from sometimes remote spots to load centers can be wasteful due to a lack of reactive power. Let's review the difference between real power and reactive power.

- Real power (also known as effective power) delivers energy from the generation source to the load. It is measured in volts, amps and watts.
- Reactive power, measured in volt amperes reactive (VARs), does no actual work. It could be regarded as the form of electricity that creates or is stored in the magnetic field surrounding a piece of equipment.

Reactive power does not travel well. Doubling the amount of power consumed quadruples the amount of reactive power needed. Long transmission lines operating at heavy loads consume VARs. Failure to address reactive power on these lines can lead to conductor heating and voltage failure. If the voltage sinks too low, the consequences can be electric system instability or collapse, motor damage and electronic equipment failure. If the voltage goes too high, it can exceed the equipment's insulation capabilities and lead to dangerous electric arcs.

The usual solution is to place static and dynamic devices close to power loads. This lowers the reactive current demand on the transmission system. Static devices are relatively low cost but are slow to respond. Their output drops when voltage drops. The best approach is a combination of static and dynamic sources. Synchronous condensers are a dynamic source. They offer immediate response to power fluctuation and can supply or absorb VARs to smoothly balance the electrical system.

5,000 HP acceleration unit designed and built by EME Corp. using a Koenig Engineering starting & turning gear module with duo-concentric SSS turning gear and starting clutches installed to automatically connect/disconnect the acceleration system to the generator

GT conversions

It is a fairly simple and inexpensive matter to convert a GT or ST generator for use as a synchronous condenser. It can either operate purely as a synchronous condenser or can be set up to deliver real power or reactive power whenever desired.

Conversion is achieved by installing a synchro self-shifting (SSS) clutch between the turbine and the generator. The turbine brings the generator up to speed. Once the generator synchronizes with the grid, the turbine disconnects from the generator and shuts down. The generator uses grid power to keep spinning, constantly providing leading or lagging VARs as needed. The clutch disengages the prime mover and the generator when reactive power is needed. When real power is needed, the clutch automatically engages for power generation.

Steam turbine conversions

It is not always economically feasible to install or retrofit a clutch between a steam turbine and generator, particularly an existing machine that has been in service for many years. In this case, it often easier and cheaper to physically disconnect the steam turbine from the generator, either seasonally or permanently. Instead, add an acceleration system to the exciter end of the generator to be used to accelerate the generator to synchronous speed so the generator can be connected to the grid as a synchronous condenser. A clutch between the acceleration system and exciter enables the acceleration system to be automatically disconnected and shut down. If power generation is needed in the area seasonally, say summer or winter, the steam turbine could be physically reconnected and MW's and MVARs would both be available.

Size 220 SSS Clutch installed in 30 MW peak load steam turbine generator plant with Rolls Royce Avon gas turbines in 1971 in Sweden continues to provide synchronous condensing; reactive power, spinning reserve and grid inertia.

The retrofit of an acceleration system should take into account the power to initiate generator rotation and overcome generator losses up to full speed when synchronizing to the grid. A thrust bearing should be included in the acceleration system to axially position the generator rotor until it is connected electrically. Depending on generator size, it might be desirable to include a turning gear into the acceleration package, as the turning gear of a large steam turbine generator is most often located between the ST and the generator. Therefore, when the ST is disconnected or removed, the turning gear is removed as well.

Retrofit considerations

Changes to existing machines in order to repurpose them can sometimes be challenging. The first consider is space. Is there enough room in the turbine hall to enable an acceleration system to be installed? Sometimes the generator is placed close to buildings walls leaving insufficient axial room. At other times, the foundation under the generator may not extend far enough to accommodate the acceleration system. In such a case, the system can be installed on the mezzanine floor on a few inches of concrete. Suitability for support of this additional equipment must be considered.

How about power for the acceleration system? Full speed windage losses as well as the excitation losses when the generator is being connected to the electrical grid need to be determined or estimated. The amount of power the acceleration system will need is also influenced by the presence of modern digital controls or if the machine has a synchro scope that requires more time to get the frequency, phase and voltage in sync with the electrical grid. In addition, the time desired to start and connect the synchronous condenser to the grid must be determined i.e., the amount of power needed to accelerate the generator inertia within a specified time. All this must be calculated to calculate the size and power of the drive.

Once power is determined, the next step is to consider how to transmit it through the existing generator exciter. Original ST generator exciters were never designed to take in power through the non-drive end. Some models even have a permanent magnet generator (PMG) on the end. Some machines can have the PMG removed and use external excitation. If the exciter shaft has a torque limitation, the acceleration time can be extended to limit that portion of the acceleration system's torque.

The generator typically shares a lubrication system with the turbine, often located on a floor below the turbine generator. In some cases, it is simpler and cheaper to install a replacement lube system, sized for the generator and acceleration system requirement only, and to locate it adjacent to the generator.

If there is no bearing lift oil system, the breakaway torque from the acceleration system may be too high. In some cases, generator bearings can be converted to have lift oil. Alternatively, a large turning gear can be incorporated.

Finally, control system modifications will be needed to make the whole system work with the addition of the clutch, the acceleration system drive and any new lubrication system. The extent of controls changes will depend on the desire to keep as much of the original plant's controls or upgrade to new PLC-based equipment.

New generators

Clutches can, of course, be installed on new generators. When gas turbines are being specified, it may be wise to include a clutch. This provides insurance against changes in policy or sudden reductions in plant usage rates. If the power output of the GT lessens significantly, the plant may be able to gain revenue by offering synchronous condenser services.

By doing so, power plants and turbine owners gain the ability to provide or absorb VARs to correct a lagging or leading power factor. They can also meet peak VAR requirements without reducing the output of generators. Incorporating a clutch in a peak load generator enables maximum flexibility and increases the potential return on capital investment over the lifetime of the installation. ■

Morgan Hendry is President of SSS Clutch of New Castle, Delaware, a manufacturer of the large clutches that are used in synchronous condensers. For more information, visit SSSclutch.com

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Cogeneration plant undergoing extensive upgrades

BOILER BEST PRACTICES

BOILER UPGRADES AND HRSG INSTALLATIONS REQUIRE CARE

BY KEVIN SLEPICKA

There are many aging boilers out there in urgent need of replacement. Whether they are in refineries, power plants or combined heat and power (CHP) facilities, there are many factors to take into account in boiler or Heat Recovery Steam Generator (HRSG) selection, installation, cost and maintenance.

Boiler selection

Some sites are suitable for a package boiler fabricated in a factory and shipped to the site for installation. Their standardized sizes don't fit the needs of some refineries and power plants, but those that can make them work often gain a good boiler at lower cost.

Beyond a certain size, though, it becomes prohibitive to ship packaged boilers. That's where stick-built (or customized) boilers come in. They are tailored to the individual facility, with components shipped to the site where they are assembled and welded. They are more expensive and take longer to install as they are made to specific site and process conditions.

A hybrid approach combines elements of package and stick-built boilers. Design is done to facility specifications. It is preassembled and tested at the manufacturer's site before being transported in one or more pieces for installation and commissioning. This greatly reduces the amount of onsite construction work that needs to be done, hence their lower cost compared to stick-built alternatives.

A large ethanol plant in the U.S., for example, needed a boiler to that could provide 290,000 lbs of steam per hour at 250 psig and 555°F of superheat. It also needed to rapidly ramp up or down in response to demand. Rapid ramping requires a maximum heat release of less than 80,000 Btu per hour per cubic foot, which places a limitation of about 200,000 pounds per hour on the size of unit that can be shipped. A hybrid approach was preferred.

The convection section, and the mud and steam drums were manufactured and shipped to the field for installation. The tubes were attached in the field. The boiler can ramp from 20% to 100% load in about five minutes without breaking down due to thermal stress. Oversized downcomers are positioned out of the heat path. This eliminates deviation from nucleate boiling where steam goes up the downcomers and fights with the water coming down (a common cause of rupture).

Sizing considerations

Large power plants, refineries and petrochemical facilities can cost tens and even hundreds of millions. A boiler represents

a tiny fraction of overall costs. But an unreliable boiler or problematic HRSG can bring the facility to a standstill.

Sizing boilers with little margin, therefore, may be ill-advised. Smaller boilers that constantly run near capacity may be cheaper, but reliability eventually becomes an issue due to constant wear and tear. They may suffer from water carry over from the steam drum to the superheater. Eventually the superheater blows out.

To minimize unscheduled downtime, it is generally advisable to specify large furnaces, steam drums and oversized boilers. A larger steam drum offers more separation to more easily remove water from the steam before it arrives at the superheater. And in the event of loss of feedwater flow, a large steam drum provides operators with valuable minutes to address the situation before steam levels fall and a trip is triggered.

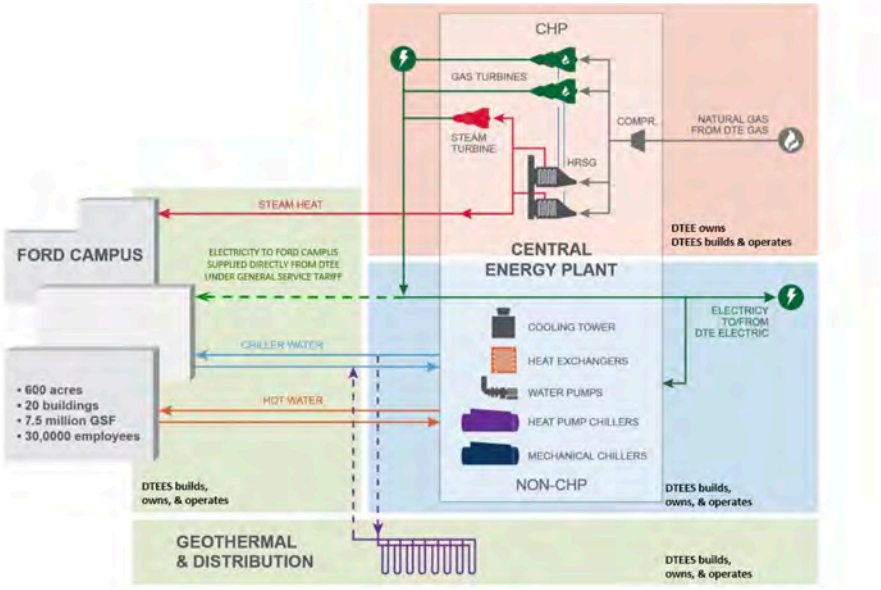
By running the boiler well below capacity, the likelihood of a breakdown is greatly lowered. Warranty problems can also be avoided. A more conservative approach to specification helps the facility gain a more reliable boiler for a small increase in cost. In the long run, it usually turns out to be far cheaper than trying to keep a smaller boiler constantly running at or near capacity.

Take the case of the new CHP plant at Ford's Dearborn, Michigan campus. It was originally specified at 23 MW to include two Solar Mars 100 gas turbines and a 3 MW condensing steam turbine. While this meant lower capital and operating costs, it didn't allow for fluctuating steam and electricity requirements, or future expansion. In partnership with developer DTE Energy, Ford opted for a larger facility that could generate enough electricity to be sold externally.

A new design called for two 14.5 MW Solar Titan 130 gas turbines, a 5 MW condensing steam turbine from Siemens and Rentech HRSGs. The facility is designed to produce heating, steam and electricity for internal use as well as feeding the grid. The 34 MW, 370 k-lb/hr steam CHP plant offers enough steam load for Ford, and optimized sizing to provide electricity for the grid. Ford gains long-term contracts for steam and power from DTE as well as an on-site generation, greater energy efficiency and lowered emissions.

Emissions changes

Older boilers are often a source of regulatory concern. When upgrading or adding a new boiler, the specification of larger furnaces is a good way to curtail emissions and minimize problems with flame impingement. Selective Catalytic Reduction (SCR) and LoNox burners can also lower NOx production.



The layout and power generation configuration of Ford's new Central Energy Plant. Courtesy of DTE.

Coal-burning and simple cycle gas turbine facilities in some areas face new regulations that severely limit emissions. California, for example, has set targets to reduce greenhouse gas (GHG) emissions to 40% below 1990 levels by 2030. It includes a 20% reduction in emissions from oil refineries. This is forcing many to replace older coal-fired boilers. Those that desire onsite power as well as process steam are switching to natural gas-fired combined cycle plants. This requires the addition of an HRSG.

Example: Morning Star Packing is a California-based producer and packager of tomato-ingredient products. It decided to install new boilers, combustion systems, and an SCR system at one facility to double steam production while lowering NOx emissions. Morning Star opted for two boilers from Rentech with register burners and an SCR system by John Zink Hamworthy. The register burners brought NOx levels down to less than 30 ppm, which the SCR then reduced to 5 ppm. Boiler efficiency was raised from below 80% to around 85%, thereby lowering fuel expenditure.

Design for the site

No two refineries or power plants are identical. Equipment and products produced can vary considerably. One facility may require an abundance of steam from a boiler that follows steam load and can fire up or down on demand. Another site demands recovery of waste heat to raise efficiency and lower emissions. And a third may suffer from severe space constraints that limit options. Thus, a cookie-cutter approach to specification can lead to problems. The owner requirements, the needs of the process and the conditions of the site should ultimately determine the boiler selected.

An east coast refinery serves as a case in point. It had to deal with new regulatory requirements to install expensive emissions equipment to cut NOx and SO2 emissions. This included leak detection and repair, SCR, Continuous Emissions Monitoring Systems (CEMS), reduction and eventual elimination of fuel oil burning, and ultra-low NOx burners to help bring NOx emissions below 0.040 lb per mmBTU.

An important part of meeting its refinery steam requirements was the replacement of older boilers with two more efficient units that brought emission levels to the required range. These units came with water-cooled membranes, accelerated natural circulation of the water, and burners that could use natural gas or refinery gas. Each boiler could deliver 250,000 lb/hr of superheated steam at 575 psig and 730º F. In conjunction with all the other emissions control technologies, this brought NOx emissions down to 2 PPM, CO to 20 PPM and NH_3 slip to 5 PPM.

Another design feature specific to this site was redundancy. Each boiler can produce enough steam to run the entire plant, with the other on hot standby. Each has dual fans as well as monitoring and safety systems. Each boiler comes 1,200 RPM forced draft fans from Robinson Industries driven by a Dresser-Rand steam turbine with a Lufkin gear. The turbines are controlled by a Woodward electro-pneu-

Every site has a different layout and different needs. Boilers must be tailored to those needs.

matic governor with a Flowserve Valtek pneumatic actuator.

Lowering operating costs

Aging household appliances are far less efficient than the latest models. Similarly, aging boilers, some dating back to the early days of the Cold War, can be costly to run and have higher emissions. By adding high-efficiency, natural gas boilers, fuel costs can be slashed and emissions lowered.

The reason for such gains is the evolution of technology. The latest generation of equipment comes with features such as SCR and LoNox burners integrated into the boiler. Modern designs lower the amount of refractory, so operators don't need to worry about replacing refractory seals or rebuilding refractory walls. Additionally, placement of the superheater in the convection section protects it from hot exhaust gas, boosts reliability and extends lifespan.

Oregon State University (OSU), for example, replaced aging boilers with a CHP plant. The new facility consists of a combustion turbine from Solar Turbines, an HRSG, an Elliott steam turbine and two auxiliary boilers. This provides all the steam as well as half of the electrical needs of the 570-acre OSU campus located in Oregon.

The central steam plant hadn't been upgraded since 1948. The replacement facility had to comply with Oregon's State Energy Efficiency Design (SEED) i.e., exceed code efficiency requirements by at least 20%, and lower emissions. The campus uses absorption chillers, so there is little fluctuation in electricity demand throughout the year. Steam is used for heating, cooling and humidification the buildings, providing hot water, sterilizing greenhouse soil and lab experiments.

The new CHP facility consists of a 5.5 MW Solar Taurus 60 engine that can run on multiple fuels (natural gas, distillate, biodiesel or methane), a Rentech HRSG with a preheater, duct burners from R&V Engineering, two auxiliary package boilers with LoNOx burners, each capable of 85,000 lbs of 200 psig steam per hours, a 1 MW Elliott backpressure steam turbine generator, and an Emerson Delta V control system. The plant can produce up to 6.5 MW of electricity and up to 280,000 lbs. of steam per hour. By switching from utility to onsite power, the university estimated annual savings of more than half a million dollars. ■

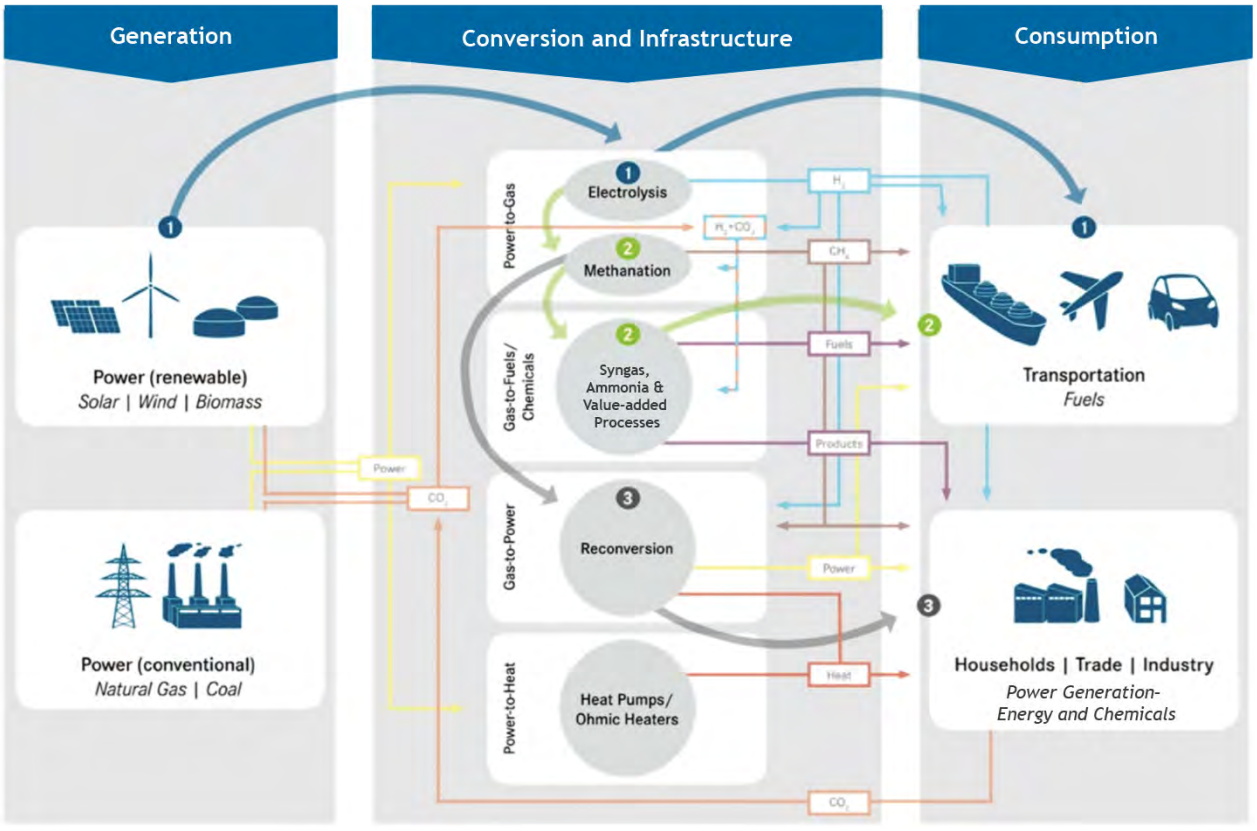
Kevin Slepicka is Vice President of Heat Recovery Boilers at Rentech Boiler Systems, a company that provides boilers and HRSGs. For more information, visit www.rentechboilers.com

How to Maintain Boiler Health

Proper maintenance can extend the life of an aging boiler by several years. Tuning is also needed to counter gradual output and efficiency degradation caused by soot or corrosion buildup.

Maintenance best practices include:

- Regularly measure conductivity or total dissolved solids (TDS) to determine blowdown rates
- Maximize efficiency by implementing automatic control of boiler excess air
- Each day check that water treatment is functioning properly
- Look for and eliminate steam system water hammer monthly
- Monitor and assess fuel costs for steam generation on a quarterly basis.
- Benchmark steam production, efficiency and quality to verify that dry steam is being generated
- Annually inspect the boiler, deaerator, feedwater tank, chemical treatment equipment, piping, valves, pressure reducing stations, heat exchangers, coils, air vents, vacuum breakers, flash tanks, condensate pumps and fittings
- A properly maintained boiler is likely to outlast plant personnel so include knowledge transfer and comprehensive documentation.
- Monitor the air-to-fuel ratio: CO forms instead of CO_2 if airflow is inadequate, releasing less than one-third the amount of heat. Excess air leads to heat getting carried away by excess stack gas. Efficient operation, therefore, depends on maintaining the proper air-to-fuel ratio.
- Keep heat transfer surfaces clean of deposits such as calcium, magnesium and silica as this lowers thermal conductivity, retards heat transfer and leads to overheating and tube failures. A 1/64 inch layer of iron plus silica scale formed by high pressure steam can produce a 3.5% fuel loss. A rise in flue gas temperature often indicates deposit formation.
- Use water softeners, demineralizers or reverse osmosis to prevent scale. Additionally, proper blowdown practices and the addition of scale retardant chemicals to water are further preventive measures.



There are a variety of different applications for Power-to-X, some of which are included above.

WHAT IS POWER-TO-X?

HYDROGEN TURBINES AND POWER-TO-X TECHNOLOGIES IN CARBON-NEUTRAL ENERGY SYSTEMS

BY CHRISTER BJÖRKQVIST

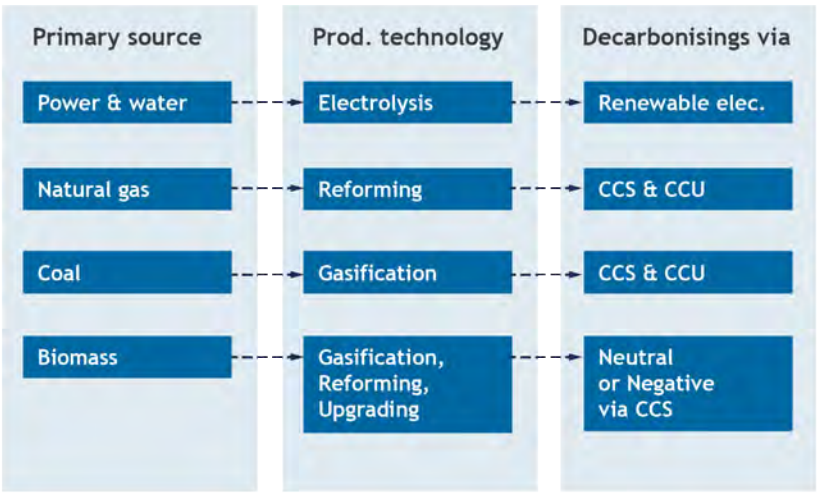
Power-to-X is an umbrella term for a number of conversion, storage and reconversion pathways that use surplus electric power from renewable energy, typically solar and wind. "X" stands for the type of energy into which the electricity surplus is being converted. These are generally gases, liquids or heat.

Efforts to cut carbon emissions and improve local air pollution require changes to how energy is produced and consumed. The European "Green Deal," for example, is a set of policy initiatives from the European Commission with the aim of making Europe climate neutral by 2050. It includes the phase out of coal, a substantial increase in renewable generation and ambitious targets to cut greenhouse gas (GHG) emissions by 2030.

Wind and solar energy represent the main pillars of these plans, but hydrogen has a complementary role. It is seen as a way to enable large-scale integration of renewables into the power generation network; as a means of distributing energy across sectors and regions, and as a storage buffer to increase system resilience. Wind and solar require large-scale energy storage to compensate for short-term and seasonal imbalances. Due to the orders of magnitude involved, this can best be achieved by converting excess electricity using various Power-to-X concepts.

Hydrogen can be produced in numerous ways including fossil fuels, biomass, crops, nuclear energy and from renewable energy sources, such as wind, solar, geothermal and hydroelectric power. This diversity of potential supply sources is why hydrogen is seen as the ideal energy carrier. The main Power-to-X concept being targeted uses excess renewable electricity production from wind and sun to split water into hydrogen and oxygen in an electrolyser. As the hydrogen is produced from purely renewable sources, this is known as green hydrogen.

In the transition phase, natural gas reforming would be required. This is a carbon-neutral resource if carbon capture technology is utilized. The reforming of hydrocarbons is seen as a kick-starter to the provision of sufficient hydrogen supply at short notice, enabling the creation of the necessary hydrogen infrastructure. This includes investment into gas grids. Meanwhile, existing assets and infrastructure can be used with adapted gas turbine technology to reduce the carbon footprint of



There are various approaches to decarbonization depending on the primary source. CCS means carbon capture and storage (or sequestration). CCU means carbon capture and utilization.

power generation and oil & gas. The scalability of gas turbines from small decentralized to large centralized systems offers enough flexibility in terms of production capability and local storage requirements.

Power-to-X concepts also offer an opportunity to reduce GHG emissions in heavy transportation vehicles, ships and air traffic. For instance, synthetic kerosene obtained using electricity from renewables is currently the only fuel enabling climate-neutral flight. Linking traditionally separated sectors of the energy system like electricity, gas, heat and transport, can raise energy efficiency and lower network investment costs. This is known as sector coupling. For example, coupling hydrogen gas turbines with other industries (e.g. chemicals and refineries) enables waste heat to be used.

Power-to-Gas is the most promising concept as it can provide significant amounts of hydrogen or synthetic methane utilizing excess electrical power from renewables to produce a gas fuel. Electrolysis is used to produce hydrogen, which can be used directly or converted to syngas, methane or liquefied petroleum gas (LPG). The resulting gases can either be used as chemical feedstocks, burned to produce heat or converted back into electricity using gas turbines and gas engines. In addition, power-to-gas opens the door to long-term energy storage of clean electricity for use in all other energy consumption sectors.

Power-to-Liquids is a process that adds carbon dioxide to hydrogen to produce ammonia, methanol or kerosene. If the added carbon comes from biomass, sewage sludge or is extracted directly from the air, it is CO2-neutral. These fuels are easier to store and transport than pure hydrogen and can be used as feedstock in industry. For example, 150 GWh could be stored in one 50m x 30m liquid ammonia tank. Underground storage could also be used, especially salt caverns as a space-efficient long-term storage option.

Power-to-heat works either by resistance heating or via a heat pump. Large heat pumps in district heating systems with thermal energy storage are an especially attractive option for power-to-heat or cold as they offer an efficient way to make use of excess wind and solar power.

A hybridization layout is being developed and demonstrated as part of a European Commission-funded PUMP-HEAT project. It is based on the coupling of a fast-cycling heat pump (HP) with a combined cycle (CC) power plant. The project aims to enhance performance under any climatic conditions. This approach can be applied to new or existing plants and to an entire fleet to improve power flexibility and efficiency. Integration of a CC, HP and cold/hot thermal storage can reduce the minimum environmental load (about 50% of full output, operating at lower loads, can reduce combustion temperature, reduce the conversion of CO to CO_2 and potentially exceed permitted emissions.). It can also raise power ramp rates, increase electrical grid resilience and improve gas turbine flexibility. Further, it demonstrates that Thermal Energy Storage (TES) combined with a heat pump can be integrated into CCs as an equivalent to conventional electrical storage at lower cost.

Turbine innovation

The current turbine fleet is optimized for natural gas but can probably handle up to 5% hydrogen without modification. Fuels with higher hydrogen content or pure hydrogen demand modifications to the combustion system, greater fuel flexibility and improved safety measures.

Technologies were developed for Integrated Gasification Combined Cycle (IGCC) plants that can burn gas mixtures with high amounts of hydrogen. However, they typically use dilution agents such as water or nitrogen that reduce efficiency, increase complexity and add costs. Some industrial scale gas turbines are under development that can burn gas mixtures with high hydrogen content (up to 100%) without dilution. However, they may not offer sufficient fuel flexibility. This is an area ripe for turbomachinery innovation.

With little to no modification, a blend of hydrogen and natural gas can be transported within the existing gas infrastructure. A new or retrofitted piping infrastructure, though, would be necessary for 100% hydrogen transport. Combusting hydrogen at the point of production could solve this problem during the initial phase of the transition.

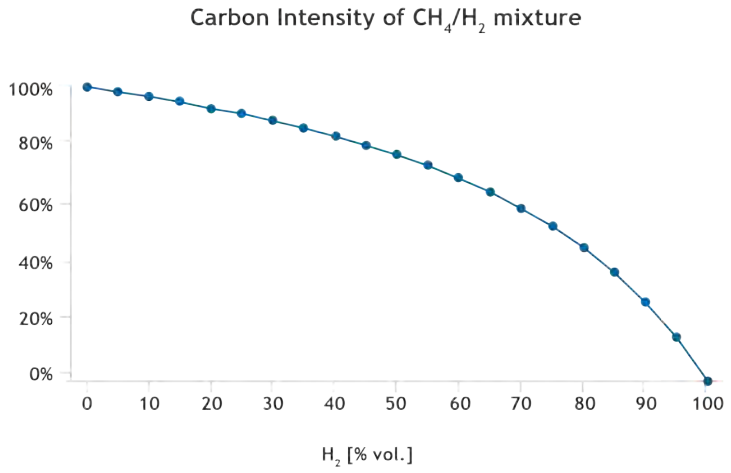
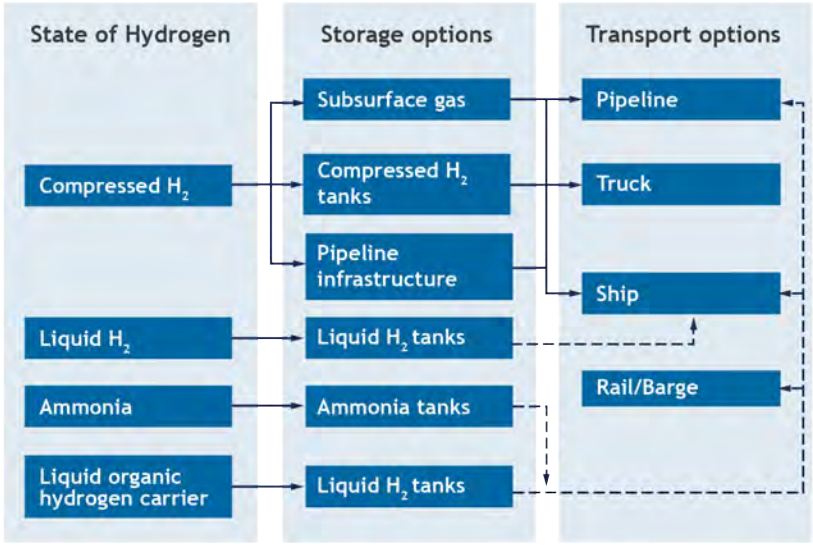


Figure 1: Carbon content in a methane/hydrogen mixture. There is a non-linear dependency of carbon content in fuel versus volumetric hydrogen content. Therefore, high hydrogen content is required to maximize the impact on CO_2 emissions.



Options for storage and transport of hydrogen, depending on its state.

Another vital area of research concerns system dynamics and how best to integrate fluctuating renewables. Cooperation is needed between hydrogen producers, end-users, gas turbine manufacturers and academia to demonstrate technology effectiveness in a timely and cost-efficient way. Key areas include combustion instability, how to maintain low NOx emissions for up to 100% hydrogen, coping with a range of natural gas and hydrogen mixtures, and addressing rapid changes in fuel composition. New materials and cooling technologies are also needed for hot gas path components.

Work is ongoing with the FLEXnCONFU project to increase the flexibility of combined cycle power units by running them partially on hydrogen or ammonia. The goal of the EU-funded project is to develop and demonstrate economically viable and replicable Power-to-X-to-Power solutions.

All available options for the effective and flexible use of surplus power from renewable energy will be combined to level the power plant load by converting electricity into hydrogen or ammonia prior to converting it back to power. The hydrogen co-firing concept will be demonstrated at EDP's 1.2 GW Gestão da Produção de Energia Ribatjo power plant in Portugal. ■

Christer Björkqvist is Managing Director of ETN Global. The mission of the turbine network is to bring together the turbomachinery value chain to accelerate research, development and demonstration of safe, secure and affordable carbon-neutral turbomachinery-based energy solutions by 2030. Visit etn.global for details on future gas turbine research and development in ETN's hydrogen report, "The Path Towards a Zero-Carbon Gas Turbine."

CENTRIFUGAL COMPRESSOR UPGRADE

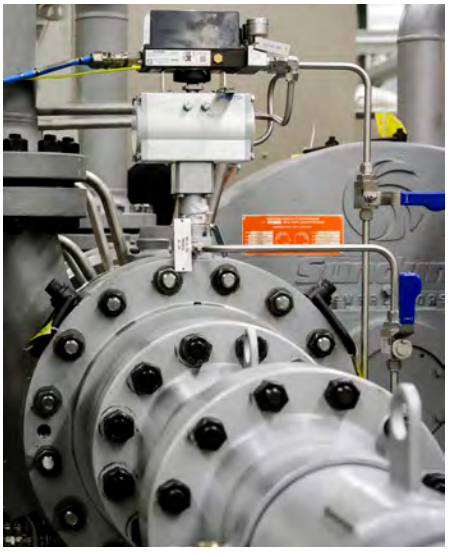
BOOSTING PLANT EFFICIENCY BY ADDING INLET GUIDE VANES TO AGING COMPRESSORS

BY DONALD DE REGNIER

The transportation industry is responsible for 70% of global oil demand. Air travel alone consumes approximately 8 million barrels per day (MBPD) of oil feedstocks. During the last few months, refineries around the globe have operated at significantly reduced capacities. As the transportation industry (and the world at large) bounces back, process conditions in refineries will change yet again. These dynamics are prompting plant operators to evaluate compressors and their control systems to ensure they operate at peak efficiency.

Centrifugal compressors used in refineries can last for 30 years or longer. Re-vamps, re-rates and upgrades to compressor components such as motors, impellers, seals, bearings and control systems extend operating life. They can also enhance performance characteristics to meet new operating requirements.

An upgrade that can boost efficiency and help refineries lower energy costs is the addition of Inlet Guide Vanes (IGVs). IGVs are a series of blades arranged at the inlet of a centrifugal compressor. Pneumatically driven IGVs pre-swirl the gas flow entering the impeller. As a result, turndown is increased while reducing the amount of work needed from the main driver.



IGVs retrofitted onto an existing Sundyne multi-stage compressor.

IGVs are especially valuable when process conditions change. When plants operate at lower capacities, they move less gas through their compressors. This alters the velocity vectors of the gas passing through the impeller of the compressors. Impellers have fixed blade angles; any change in the gas speed vector relative to the impeller blade speed vector can trigger internal stalls and begin surge conditions. An anti-surge system will protect the unit. However, opening the anti-surge valve boosts electrical or water consumption, as well as energy costs.

IGVs help to smooth out surge conditions. During turndown, the compressor control system rotates the IGV to pre-swirl the gas and adjusts the flow to fit the fixed impeller inlet blade angle. Adjustment of the internal geometry keeps the compressor within its best operating range and lowers the surge threshold. Like the wing of an airplane, each vane is designed with an airfoil cross-section. This minimizes aerodynamic losses in the full open position (vanes positioned parallel to the rotational axis). The inlet guide vanes can modulate from fully opened to fully closed positions to provide a variable degree of pre-swirl.

IGVs have long been considered a requirement for high-flow applications such as reactor feeds, gas boosting for power generation, or overhead boost in gas treatments for LNG applications. They are now standard on new equipment. But given the 20- to 30-year lifespan of centrifugal compressors, there are thousands of machines running in refineries that could implement this upgrade.

Such installations are straightforward: an IGV assembly replaces the inlet flanges, using the same bolting and interface. It does not require disconnection of any piping.

Refineries in the U.S., France, Singapore and Kazakhstan recently added IGVs to their compressors. As part of the process, each plant audited its operating conditions and compared past trends to current requirements. They made standard adjustments to boost efficiency and retrofit capacity. Additionally, they performed basic maintenance on the bearings and seals. The combination of regular maintenance and the upgrade enabled each plant to enhance turndown by up to 30% and achieve an average of 10% power savings for less than 7% of the cost of a new machine. This was accomplished in a few days during a standard turnaround without the need for hot work permits, welding or concrete work, or crane operation. In addition to boosting efficiency, IGV upgrades minimize stress on the entire system, which helps to extend the mean time between maintenance intervals. ■

IGV blades at the inlet of a compressor pre-swirl gas flow entering the impeller, reducing the amount of work needed from the main driver.

Donald de Regnier III is Aftermarket Product Manager at Sundyne, a manufacturer of compressors since 1965 with thousands of deployments in refineries and petrochemical plants. Sundyne's aftermarket services group can retrofit IGVs onto existing Sundyne multi-stage compressors. For more information, please visit www.sundyne.com or email Donald.deRegnier@sundyne.com.

OFFSHORE FILTRATION

NEW RESERACH PROMPTS REASSESSMENT OF OFFSHORE FILTRATION SELECTION

BY GRAEME TURNBULL

Air in the offshore environment contains numerous airborne particles that have the potential to harm gas turbines (GTs). These include water droplets, sea salt aerosols, salt in solution and sub-micron particulate, as well as industrial airborne particulates from burnt and unburnt hydrocarbons, drilling activities, mud burn and grit blast. When sour fuel is running, components within the turbine section are exposed to accelerated hot-end corrosion. This results from the combustion of sour fuel gas, rich in hydrogen sulphide (H_2S), reacting with salt (NaCl) from the intake air.

Cooling passages on the turbine blades must remain free of contamination. If they are not protected, blockage can result in fatigue and cracking. Variable guide vanes and pneumatic parts are particularly exposed contamination and corrosion offshore. This can lead to seizure. Air filtration systems can promote better compressor cleanliness and long-term part integrity.

Traditional filtration

In Europe, products are tested and clarified in laboratories in accordance with EN779 and EN1822 use. EN filtration efficiency grades range from G1 to U17; the higher the number, the higher the level of filtration. In the GT market, filtration typically ranges from G3 to E12. Filters in the G3-M5 range are commonly used as pre-filters.

Typically, onshore modern GT filtration systems have a minimum of an F9 classification. Systems are now regularly commissioned with levels of filtration up to EPA E12. About 85% of offshore GTs are protected by small, high velocity filtration systems that fall into the pre-filtration classification range of G3-M5. These systems were widely adopted from the late 1970s. Selection was based on research by the National Gas Turbine Establishment on an ocean-going marine vessel. It involved taking samples of air from less than 10m above sea level as an indicator of offshore air quality. What was less well understood at the time was the difference in air quality between sea and platform level (30m) where most particles are sub-micron.

Testing at that time considered that 95% of offshore particles were above 5 micron, and that filter bags would be effective in arresting them. Recent research revealed that 98% of particles on offshore platforms are 1 micron or below (Table 2).

Traditional filter bags offer minimal filtration and particle arrestance for particles less than 1 micron. They are designed to allow water, moisture or fog to coalesce as it passes through the filter bags. This creates larger droplets that are captured by a downstream vane. However, some water and salt in solution passes through the vanes. Water can collect on the floor downstream of the bags and upstream of the final vanes. It evaporates over time, allowing salt crystals to be carried into the GT.

This N-hance filtration system from AAF provides EPA E12 protection on BP's Clair offshore platform. This level of filtration can be retrofitted onto existing small, high velocity intake filter housings.

EPA E12 filtration

Air filters with EPA E12 classification capture 99.5% of particles at the Most Penetrating Particle Size (the most difficult size to capture at a predefined airflow speed.

When they first became available offshore, EPA E12 technology required a large equipment envelope. The air intake housing had to be replaced to lower airflow. This raised costs and foundation loads. That's why it is primarily used on the platforms of super-majors. They invested in upgrades when oil prices peaked.

EPA E12 filtration is now available as a retrofit within high velocity filtration systems without the need of a larger filter house.EPA E12 cost effectively captures substantially more harmful particles than other filtration classes. The upgrade is designed to deal with large amounts of moisture and salt. This type of filtration reduces water washing frequency, increases production efficiency and lowers CO_2 emissions, while providing longer operational life for the gas turbine. ■

Measurement	Particle Distribution							Summary
	<0.3 µm	<0.5 µm	<1 µm	1-2 µm	2-6 µm	6-10 µm	>10 µm	
NGTE 30 knott aerosol (<10 m ASL)	-	-	-	0.1%	4.5%	20.5%	74.9%	95% particles > 5 µm
AAF Platform Measurements	75.2%	16.3%	6.7%	0.9%	0.7%	0.2%	-	98% particles < 1 µm

Table 1: A comparison between the aerosols from the National Gas Turbine Establishment (NGTE) and AAF platform measurement, highlighting the difference in particle sizes at platform level.

Filtration Type	Filtration efficiency class	Efficiency @ 0.3 micron	0.3 micron particles/m³ air	Particles arrested	Particles penetrated	Cleanliness ratio vs G4
Offshore Traditional Filter Bags	G4 or MERV 7-9	5%	>29.2 million	1,460,000	27,740,000	N/A
AAF N-hance Retrofit	EPA E12	99.95%	>29.2 million	29,185,400	14,600	x 1,900

Table 2: Air cleanliness at 0.3 micron. AAF's N-hance EPA E12 filtration technology is 1900 times cleaner compared to traditional high velocity technology.

Graeme Turnbull, CEng, MIMechE, MIOA, is System Product Manager, at AAF International. For more information, visit aafintl.com

GEARBOX TRENDS IN TURBOMACHINERY

Patrick Potter, Director of Sales at Cincinnati Gearing Systems, discusses types of gearing, how the field is evolving and the latest trends in turbomachinery gearing.

Tell our readers about Cincinnati Gearing Systems

Cincinnati Gear was established in 1907 and was a founding member of the American Gear Manufacturers Association (AGMA). Today we are known as Cincinnati Gearing Systems (CGS). We have four facilities located on the east side of Cincinnati including two manufacturing facilities, an assembly and test center, and a dedicated heat-treating facility known as Cincinnati Steel Treating.

What trends have you observed in turbomachinery gearing

As application demands have steadily increased, the need to transmit higher powers at higher pinion speeds has followed suit. This is especially true with mobile gas turbine driven equipment, where compact packaging envelopes often result in high power-density requirements. This challenge has been met using new designs, high quality materials and precision manufacturing. On a recent microturbine project with a 74,000 rpm pinion, we employed a split-power-path gearbox design, a hybrid of an epicyclic and parallel shaft arrangement that eliminates high-speed journal bearings. This enables otherwise unachievable shaft rotational speeds, high turbine efficiency, greatly reduces gearbox power loss, and raises overall system efficiency.

How has gearing technology evolved over the last 20 years

Improved material quality, heat treat processes and machining accuracy have allowed designers to expand the envelope in terms of speeds, transmitted powers and pitch line velocities. Twenty years ago, a transmitted power of 2,000 HP on a 30,000 rpm pinion would have been considered challenging. Recently, we delivered a set of four integrally geared compressor gearboxes for fuel gas booster service to a power plant on the east coast. These units operate continuously with a pinion speed of 30,000 rpm and a rated power of 3,500 HP. All design parameters are well within our comfortable experience range.

Are there any misconceptions about gearing?

Gearboxes are often considered a necessary evil, since they simply connect the driving and driven equipment. But the gearbox also forms the heart of the package, a critical link that must operate perfectly or performance will be compromised. Clearly, quality matters. Choosing a gearbox partner with demonstrated experience and a history of customer focus helps ensure a smooth-running project.

What are the primary products you provide?

Cincinnati Gearing Systems provides custom engineered gearboxes for high-speed, high-power turbomachinery applications. We design and manufacture single and multi-pinion integrally geared machines per AGMA 6011 and API 617 for a variety of services including air separation, fuel gas boosters, propylene dehydrogenation and compressed air energy storage. We also design and manufacture epicyclic gearboxes for mobile power generation as well as fracking applications, for both mechanically driven gas turbine to pump systems and e-fracking services. Double helical stand-alone gearboxes are another offering, which we provide to the U.S. Navy for shipboard power generation and to commercial customers for compressor and pump drives.

Tell our readers about one of your products

Epicyclic gearboxes have been enjoying a surge in popularity. Compared to parallel shaft gearboxes, advantages include a coaxial mounting arrangement between driving and driven equipment, typically higher efficiency and reduced oil flow requirements. We manufacture epicyclic gearbox designs for gas turbine to generator drives, gas turbine to pump drives and compressor applications. This type of gearing in turbomachinery pre-dates parallel shaft gearing. Because of the inherent load sharing benefit of multiple planet gear meshes, epicyclic gearboxes can transmit more power in a given size range than a parallel shaft unit. More recently, oil and gas OEMs and end users have begun to seek out epicyclic gearboxes. The 4th edition of API 677, set to be released later this year, will be the first API standard to include a chapter on epicyclic gearboxes.

What are the main services you provide?

We provide engineering support services as well as rebuild and repair capabilities. We provide clean sheet designs tailored to applications, and also reverse engineering and design audit services on existing equipment, including gearboxes produced by other manufacturers. In many cases, we can recommend cost effective upgrade and re-rate options for more power and higher speed.

What has been the impact of the Covid 19?

Our management was proactive in the early stages of the pandemic in recognizing and mitigating the impact of Covid 19. We implemented remote working for office employees and social distancing for shop personnel. We bought hand sanitizer from a neighboring business (a craft distillery), and found creative supply channels for masks. As an essential business, we never missed a day of work and have not laid off any employees. In fact, we are in a strong growth mode and have continued to hire during the pandemic. While we suffered some slowdowns at a few of our sub-suppliers, these bottlenecks have been resolved and we are looking forward to business as usual throughout the rest of 2020. ■

WEBINAR REPORT

BY RORY PASQUARIELLO

Trade shows, conferences, and workshops remain postponed or cancelled. In response, Turbomachinery International has increased the frequency of webinars.

In partnership with industry leaders, Editor-in-Chief, Drew Robb, hosted three online workshops: "How Connectivity Enables Comprehensive Asset Health Monitoring to Enhance Productivity, Minimize Downtimes and Boost Safety" on May 13; "Strategies and Tips on How to Emerge Strongly from Uncertain Times" on May 21; and "The Gas Turbine Market: Where It's Been, Where It's At Right Now, And Where It's Heading," on June 18.

Connectivity in asset health monitoring

On May 13, Robert Bradshaw, Global Software Sales Leader at Bently Nevada, and Chris Kramm, Product Manager for System 1 at Bently Nevada, discussed turbomachinery operations, connectivity in condition monitoring systems and how inputting process and control data can enhance a monitoring system. Having a connected condition monitoring platform with the ability to import and export other types of data is essential to an overall asset health monitoring strategy. Strategies discussed include how to increase productivity, how to lower the frequency of machinery breakdowns and how to reduce maintenance costs.

Emerging from uncertain times

On May 21, Mark Axford, a veteran Gas Turbine and Power Industry Consultant, Axford Turbine Consultants and Editor in Chief Drew Robb, briefed the audience on how to emerge stronger from challenging times. They covered the Covid-19 pandemic and ensuing economic disruption, as well as the collapse in oil prices. Additionally, the webcast provided historical perspective from past recessions and market downturns. Axford and Robb offer tools and tips to help companies cope with immediate problems as well as strategies to recover faster from the downturn.

The future of gas turbines

Our best attended webinar to date with almost 600 registrants was, "Gas Turbine Market: Then, Now and the Future!" a webcast hosted by Turbomachinery International Magazine on June 18, 2020. It addressed the state of the market as of 2019, how gas turbine orders are trending overall and how the market has changed in light of current events. The featured speaker Tony Brough, President of Dora Partners & Company, an energy-focused management consulting company, covered the aeroderivative turbine market in detail as well as the market for large heavy duty machines and small turbines.

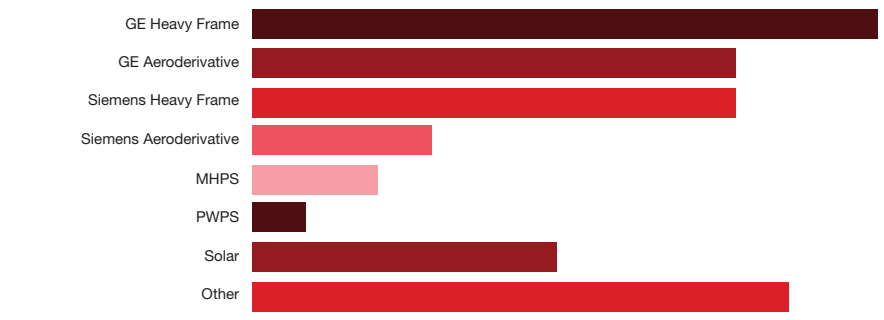
During the webinar, a survey of attendees revealed that those specifying or purchasing gas turbines selected alternate fuel capability as the most important factor. This trend is probably being driven by renewed interest in hydrogen-powered gas turbines, as well as ongoing efforts to further reduce emissions.

36.1% chose alternative fuel capability as the most critical deciding factor in turbine selection, 28.4% gave the greatest emphasis to higher combined cycle efficiency and 21.9% to better simple cycle efficiency. Only 13.5% of respondents picked dry low emissions.

The survey also asked users which type of gas turbines they primarily operate, manage, supply or service? 22% of respondents primarily use GE Heavy Frame turbines and 17.3% use GE aeroderivatives. Siemens Heavy Frame users gained 17.3% while Siemens aeroderivative users represented 6.4%. 10.9% of respondents use Solar equipment with 4.5% using turbines from Mitsubishi Hitachi Power Systems (MHPS).

All webcasts are available for replay at turbomachinerymag.com. ■

Which type of gas turbines do you primarily operate, manage, supply or service?



If you were purchasing or specifying a new gas turbine today, what would be the most critical technical aspect you would be looking for?

Oil & gas pumps

Xylem has expanded its oil and gas pump portfolio to include: e-MP multistage ring section pumps, e-XC single-stage double suction centrifugal pumps and larger vertical turbine pumps. These pumps are customizable to meet the demands in upstream and midstream applications, from source water and produced water to liquid transfer.

e-MP – The multistage ring section pump is best for high-pressure applications, such as produced water and crude oil Lease Automatic Custody Transfer (LACT) units.

e-XC – Designed for durability and performance in harshest, the e-XC comes in multiple models and configurations to handle various aggressive applications. A corrosion-resistant stainless steel impeller and wear rings are standard.

Vertical turbine pump – This extension to the existing Xylem vertical turbine product has capacities up to 1.7 million barrels per day.

Xylem.com

Xylem e-XC single stage double suction centrifugal pump

Pressure regulator

BelGas has introduced a large-volume regulator for natural gas, propane and other fuels known as BelGas P1098. It is pilot-operated and has a large-area actuator diaphragm, allowing for fast response for modulating flow conditions. The pilot acts as an amplifier for the main regulator valve. Pilot assemblies can be exchanged in the field. It can deal with pressures of up to 400 psi. All venting/loading pressure bleeds downstream so there is no atmospheric relief. Applications include commercial buildings, boilers, furnaces, ovens, plant air systems and liquids. It is available in 2" and 4" pipe sizes, flanged and screwed, with 25 possible spring ranges, and eight pilots.

marshbellofram.com

Turbomachinery protection

When unsheltered storage is the only option, MilCorr VpCI Shrink Film can be used for preservation and corrosion protection of assets of all sizes, from aircraft to offshore equipment and operational turbomachinery spares on outdoor racks. By heat-shrinking it to fit the shape of the object, asset owners can create a tight and tamper-proof protective environment. The film provides multimetal corrosion protection via contact and vapor-phase molecular action of the corrosion inhibitors within. It also offers UV protection and provides a durable physical barrier effective even in severe outdoor climates, including hurricanes, high temperatures, humidity and chloride-ridden air. It replaces conventional rust preventatives such as oils and desiccants. Parts protected with MilCorr VpCI Shrink Film are ready to use immediately after removal.

cortecvci.com

Accelerometers

Piezo-electric seismometers by Sensonics provide output of up to 50V/g and measure frequencies down to 0.1Hz. PZS Accelerometers are used in machine condition monitoring. The PZS range of low-noise accelerometers can be used for monitoring pumps, fans, motors, centrifuges, gearboxes, compressors and process equipment.

Sensonics.co.uk

Data acquisition system

ESC | Spectrum, a provider of data acquisition software (DAS) and services for continuous emissions monitoring systems (CEMS), has launched RATAView. This subscription-based software helps stack testers perform Relative Accuracy Test Audit (RATA) tests accurately to meet regulations and comply with 40 CFR Parts 60 and 75 requirements. It is packaged with an 8864 Data Controller. The software guides users through configuration of a test queue to create templates, automating the process. Users can reuse templates, in manual or automatic mode, can reset the test to clear out current results and start over, accept the test, or stop/pause. Tests are saved, and can be reported or viewed in Excel.

Envirosys.com

Laser spectrometer

Yokogawa of America has released the TDLS8100 probe-type Tunable Diode Laser Spectrometer (TDLS). Industrial process heating operations – fired heaters, boilers and furnaces – account for approximately 70% of the manufacturing sector's process energy consumption and constitute a process safety risk and source of greenhouse gas emissions. The TDLS 8100 enables operators to make safety improvements, emission reductions, optimization of fuel efficiency and yields, as well as prolong the life of assets.

The TDLS 8100 measures in situ gas concentrations, eliminating the requirement for sampling and conditioning components. It is field-serviceable with no consumables or calibration required. The single flange design allows installation where cross-duct TDLS technology was previously not feasible. It is SIL2 compliant and explosion-proof for Division 1 and Zone 1 installations.

Yokogawa.com

Bellows seal valves

Conval offers a line of Clampseal bellows seal valves. Low-pressure ASME Class 150-900 Clampseal bellows seal valves are suitable for toxic, corrosive, and caustic applications and regulation of severe service process control where leakage is not an option. They feature low weight and seismic profile; leak-proof integrity; in-line servicing; high cycle bellows; high flow capacity; no fugitive emissions. They are available in ½" to 4" with socket weld, butt weld, flange and threaded connections.

High-pressure Clampseal single and double bellows seal valves for up to ASME Class 2500 are suitable where packed valves may not reliably contain light gases or hazardous fluids due to leakage. They allow zero emissions and meet MSS SP-117 requirements. Available in 1/2" to 4", in Y, T and angle configurations, materials include carbon steel; chrome-moly; and stainless steel. Options include electric, pneumatic and hydraulic actuators; open/closed locking devices; single or dual limit switches; position indicator; and leak-off port. N-stamp valves are available.

Conval.com

Condition monitoring

Brüel & Kjær Vibro has launched the latest generation of its VCM-3 condition monitoring platform. It is designed to increase uptime and reduce lifecycle costs of pumps, fans, motors, gearboxes and other machines. It is a 12-channel data acquisition hub targeted at the monitoring of auxiliary machines, balance-of-plant non-critical machines and other assets in industries where condition monitoring is required without machine protection. It features enhanced condition monitoring measurement, easy integration, cybersecurity and installation. It also offers simultaneous input channels with high sampling frequency.

Bkvibro.com

3D printing

Velo3D has released a process for additively manufactured parts in aluminum F357 on the company's Sapphire metal 3D printing system. The foundry-grade aluminum alloy, suitable for the laser powder-bed fusion process, enables 3D printing of parts that are traditionally cast. There are other aluminum alloys that are more commonly used in metal additive manufacturing, such as AlSi10Mg. But aluminum F357 can be anodized and shares characteristics with A356, a widely used casting alloy.

The manufacturing process of aluminum F357 was developed jointly with PWR. The Velo3D system eliminates support structures for complex passageways, steep overhangs and low angles. It can produce thin wall structures and high aspect ratios. A one-meter tall system will be available this year.

The Sapphire metal AM printer by Velo is compatible with titanium64, INCONEL alloy 718, and aluminum F357.

VELO3D.com

Customized Regal tools

Regal Beloit has launched Regal Perceptiv intelligence, a matrix of digital solutions that help users engage with Regal to maximize reliability and plant production. This includes on-site and off-site diagnostics, customized monitoring, and products that connect to facility infrastructure. Augmented reality and tools allow monitoring from a smartphone, tablet, laptop or computer. It also delivers tools to find Regal online product catalogs, 3D CAD drawings, selection tools, mobile apps and QR codes on products.

RegalBeloit.com

Turbocompressor

The CT-NG is Celeroton's new turbocompressor series for noble and inert gases. Equipped with gas bearings, the first variant, the CT-NG-2000, is available for oil-free compression of helium. Besides single-stage operation, it allows for the connection of multiple units in series/parallel configurations to increase pressure ratio or mass flow. Master/slave control is achieved by bus communications. The modular CT-NG platform covers gases such as argon, neon, nitrogen and gas mixtures by making aerodynamics and gas bearing adaptions.

The sealing concept of the compressor minimizes contact of the process gas with wetted materials within the compressor and works without the need for rotating sealings. This allows the compressor to be operated in hydrogen, pure oxygen or reactive and aggressive gases. It provides tightness and low leakage rates. Applications are mainly related to contamination-free gas supply such as in the semiconductor industry, process gas applications, rapid prototyping and for cryogenics.

Enerpac.com

CAD/CAM nesting

Hypertherm, a manufacturer of cutting systems and software, released ProNest 2021, an update to its CAD/CAM nesting software for automated cutting. New features include: A redesigned 2D CAD package with improved font support and ability to shape text; a CAD editor preference for users to set a default CAD program for edits to parts in the ProNest part list; the ability to select embedded ProNest CAD software or choose third-party software; A part report opened from the part list so users can add individual part reports with an image of the part, plus dimensions, size, material, class, process and costing; interior bridge cutting to add bridges to text and interior geometry so pieces don't drop when cut, to minimize interior cutouts.

In addition, Hypertherm is releasing upgrades to its ProNest LT software for lighter production environments. Users with an active subscription, and customers with an active maintenance plan can upgrade to the new version of their respective product at no additional charge.

hypertherm.com

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MYTH: TRANSPORTING IS THE SAME AS STORING ENERGY

We are accustomed to the fact that the energy we need for transportation, heating and cooling is cheap, available and reliable. Turn on the TV – electricity; turn on the heater – natural gas. And it isn't expensive. Thus, when we discuss energy problems, it is usually about finding enough primary energy and its cost i.e., we are interested in BTU's and Dollars per BTU.

In reality, the problem is often not energy availability, but rather is the transportation and storing of energy. There are many primary energy sources such as fossil, solar, wind, nuclear, and hydro. Unfortunately, they are usually not conveniently located close to the industrial or residential consumer. Even if they are, there is often a difference between the local energy supply and demand curves. To compensate, energy needs to be transported and sometimes stored.

There are four fundamental forms of energy that can easily be transported: 1) electric energy using power lines, 2) fossil gas (mostly natural gas) in pipelines, 3) liquid fossil (mostly crude oil and various forms of gasolines) in tanker trucks or pipelines, and 4) solid fossil fuel (usually coal) by freight rail or truck. Other transported forms of energy such as hydrogen, biomass, and combustible liquids exists, but they are not an integral part of the current energy infrastructure (LNG is effectively stored natural gas so it is just a natural gas storage extension). One should note that the above four energy forms also all have different storage mechanisms, such as batteries, tanks, pressure vessels and solid storage piles.

Thus, the non-electric sources of energy that can be practically transported and stored are usually fossil fuels. Transportation and storage have costs and losses which are different for each source. They can easily be quantified but are often overlooked when reviewing the cost of energy. As for renewable energy sources, geothermal heat and nuclear power, transportation is limited by the electric grid capacity and transmission losses. We also need to consider that gaseous, liquid, and solid fuel energy carriers must still be converted to electricity in most cases, which also has associated heat engine conversion losses.

The losses associated with storage are different for the form of energy and can vary widely depending on the transportation method. For example, moving a fixed amount of energy across 100 miles using electric power lines loses 1% to 10% of the energy. In a gas pipeline, loses are 0.1% to 0.3%. A pipeline for liquids only consumes about 0.02% to 0.1% (liquid has a higher energy density per volume than gas and pumping a liquid also requires less power than compressing gas).

Storage losses are a particular issue when electricity is transported. Methods like battery storage or thermal-mechanical storage schemes have round-trip losses in the range of 5% to 10% for the former and 25% to 50% for the latter. Storing gas in caverns or tanks creates round trip losses in the range of 1% to 3%, while storing liquids in a fuel tank has practically no loss. Similarly, packing a gas pipeline, by taking advantage of the compressibility of gas, has virtually no loss. Clearly, transportation and storage of gas, liquid, and solid forms energy is far more efficient than that of electricity.

Transportation and storage of gas, liquid, and solid forms of energy is far more efficient than that of electricity.

Renewable losses

This brings us back to renewables. Renewable energy is almost always generated in the form of electricity at the source. That energy fluctuates widely and has to be transmitted to the end-user. Transport via power lines energy incurs significant transmission losses. But if the electricity is converted to a gas such as hydrogen or liquid such as diesel prior to transport, the transportation and storage losses will be much lower. For some of these options, the existing pipeline infrastructure can be utilized by blending the gas or liquid with other hydrocarbons that are being transported. Thus, electric to gas or liquid conversion is an option if the transportation and storage efficiency is critical, albeit a relatively high energy penalty is paid to produce the liquid or gas. This conversion and transportation process is still carbon neutral for hydrogen gas and can be carbon neutral for hydrocarbon liquids as long as the carbon is not sourced from a fossil fuel.

Keep in mind that if fossil hydrocarbons are transported with the intent to use carbon neutral fuel in a power plant, the options include the removal of carbon prior to feeding it into a pipeline, or the removal of carbon at the power plant. The former incurs transportation losses from flowing pure hydrogen as well as infrastructure challenges; the latter avoids these challenges. In either case, the carbon has to be sequestered. This incurs an energy penalty, mostly for compression of CO_2. If the CO_2 sequestration site is at a distance, transporting CO_2 creates additional energy losses and costs.

When you expect cheap, reliable energy, it is not just the source of energy that matters. Costly infrastructure also must be in place. Energy can be transported and stored in many forms; there is no single best solution. ■

Klaus Brun is the Director of R&D at Elliott Group. He is also the past Chair of the Board of Directors of the ASME International Gas Turbine Institute and the IGTI Oil & Gas applications committee.

Rainer Kurz is the Manager for Systems Analysis at Solar Turbines Incorporated in San Diego, CA. He is an ASME Fellow since 2003 and the past chair of the IGTI Oil and Gas Applications Committee.

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