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In this Issue...

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
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Turbo Expo 2022 Goes to Rotterdam!

ASME Turbo Expo 2022, in Rotterdam, the Netherlands maintained its reputation as the world's premier turbomachinery conference with over 1500 professionals. Throughout the week, delegates shared practical experiences, knowledge and ideas on the latest turbine technology trends with a focused theme "Road Mapping the Future of Propulsion & Power". Over 1000 peer reviewed technical presentations provided insight into the minds of industry professionals and students.

The conference theme was discussed at length during the keynote session held on Monday, June 13 moderated by Jaroslaw Szwedowicz, R&D Senior Principal Key Expert for Gas Turbine Modules, Siemens Energy AG and Christer Björkqvist, Managing Director, ETN Global. Industry experts from Uniper, Air France KLM Group, Siemens Energy AG and Shell Global International provided passionate discussions on accelerating the journey towards secure, climate neutral energy solutions.

This year's Turbo Expo held a spotlight to energy transition dedicating a day to Hydrogen Energy and Storage. Technical presentations on Wednesday addressed the challenges of moving into a net zero future. Frank Michell Founder, Power Industry Consulting, LLC and Dr. Natalie Smith, Senior Research Engineer, Southwest Research Institute moderated Wednesday's Hydrogen & Energy Storage for Propulsion & Power featuring speakers from Shell Oil, DLR, JJDS Environmental, Southwest Research Institute, and Rolls-Royce. The speakers discussed developing and deploying hydrogen technologies for generating electricity.

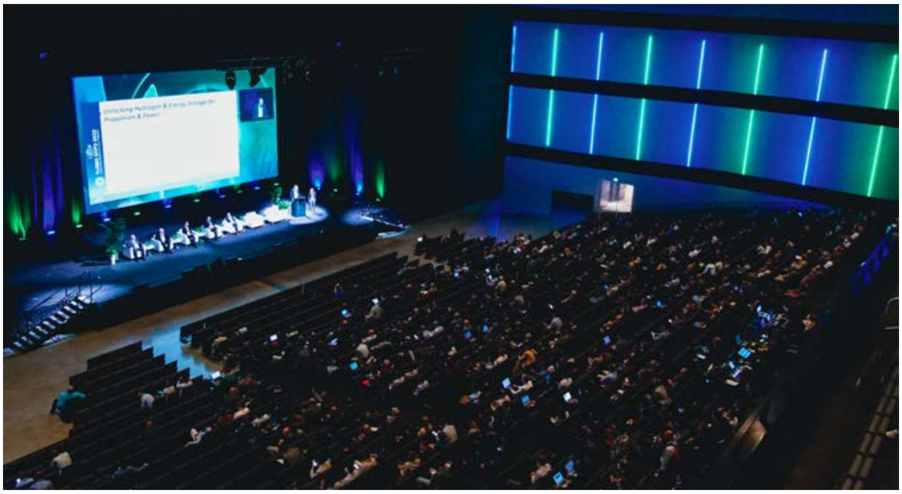
Turbo Expo 2022 buzzed with the excitement of the turbomachinery industry creating new ideas and generating productive connections between professionals. On Monday evening 1500 turbomachinery experts attended the welcome reception and enjoyed the opportunity to socialize with professionals from industry and academia after having a two-year hiatus from in-person Turbo Expo. The Celebrating Women in Engineering networking event was a great success. Virginie Barbieux, Sr. Product Engineering Manager at Cadence and Natalie R. Smith, Ph.D., Group Leader - R&D Rotating Machinery Dynamics, Southwest Research Institute provided motivating talks overlooking the Nieuwe Maas River and lights of Rotterdam. Students gathered Wednesday evening to socialize and connect with other individuals passionate about turbomachinery and future of the industry.

This year's three-day exhibition featured almost 90 exhibitors from 14 countries. The delegates had the opportunity to visit the exhibition both in-person and online. Those that were onsite in Rotterdam were welcomed by the smell of a Rotterdam favorite, Stroopwafel, served from the Cadence Design Systems booth and a Tuesday afternoon Dutch Gas Turbine Association reception featuring local Dutch drinks.

The exhibition floor is now open for ASME 2023 Turbo Expo in Boston. Contact igtiexpo@asme.org for sponsorship and exhibiting opportunities to meet your marketing budget and find the Exhibition floorplan online at www.turboexpo.org to select your location.

A special thanks to the sponsors that support the event. At the Platinum and most prestigious level, Rolls-Royce plc; Silver was Ansys and Flownex Simulation Environment; Bronze included Baker Hughes, Cadence Design Systems, Inc, Kingsbury, Inc, NASA, SoftinWay Incorporated and Solar Turbines. Additionally, we had support from Advanced Design Technology Ltd, Concepts NREC and GE. We cannot succeed without the generous support of our sponsors!

Please plan to attend Turbo Expo 2023 in Boston, Massachusetts, USA, June 26-30 to participate in the turbomachinery industry's most highly recognized conference and exhibition.



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“As the Turbine Turns...” • #50 • August/September 2022

Pelton Turbines: Elegant and Efficient

By Lee S. Langston, Professor Emeritus, University of Connecticut, lee.langston@uconn.edu

The Sierra Nevada goldfields of Northern California in the late 1800s would seem to be an improbable setting for the development and invention of a new, innovative turbomachine.

Goldmining in the mountains of California required lots of rotating machinery to run pumps, foundries, stamp mills and crushers. To provide power, there was a major expense of importing steam engines and boilers, whose use quickly taxed supplies of local timber for fuel.[1] Water was in abundance with high head, but relatively small volume flow rates were naturally the rule.

Seeing the need for an improved power source, Lester Allan Pelton[2], born in an Ohio log cabin in 1829 and a goldfield millwright and practicing engineer, in 1880 patented[3] a new improved hydraulic water turbine, now called a Pelton turbine.

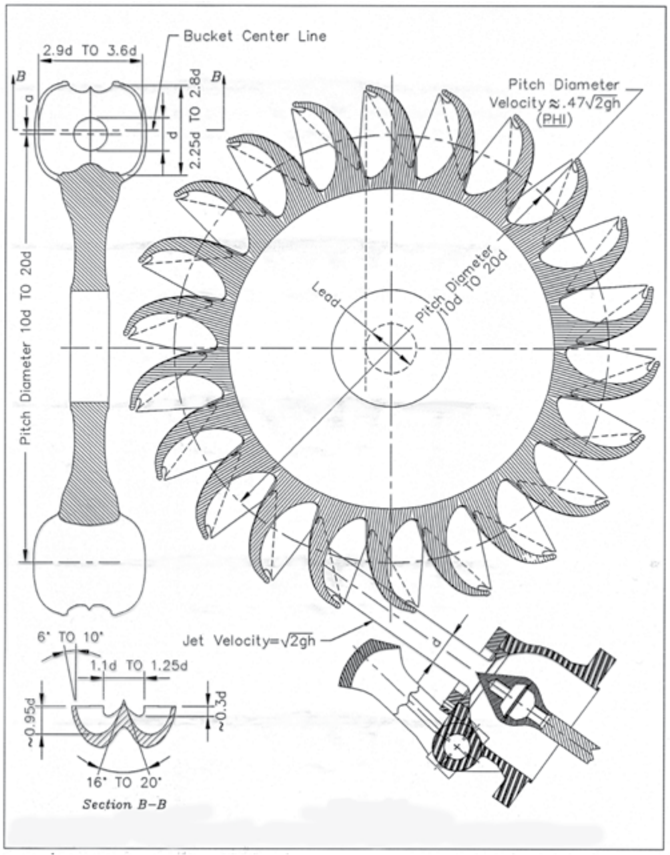

Figure 1. Pelton turbine components for a modern water power plant.[7]

A strikingly simple turbine, it consisted of an undershot water wheel with Pelton’s newly invented divided buckets (or blades) fixed to the rim, which bifurcated and deflected a high velocity water jet directly at them, to rotate the wheel. The new Pelton wheel resulted in an impulse turbine which easily doubled the thermal efficiency of the standard water wheel, raising from 30-40% to as much as 85%.

For us in the gas turbine community, two kinds of turbines occur in axial flow engines, reaction and impulse.[4] In a reaction turbine, the relative discharge velocity increases and the pressure decreases in the passages between rotor blades. In an impulse turbine (e.g., the Pelton turbine) the relative discharge velocity of the rotor is the same as the relative inlet velocity since there is no net change in pressure between the rotor inlet and rotor exit.

Having worked for a good part of my engineering career on the complex blade passage fluid mechanics of jet engine reaction turbines,[5] I have always been intrigued by the simpler, less-complicated flow field on Pelton turbine blades (or buckets) and the ease which Pelton’s invention was able to achieve such high efficiencies, early on.

Pelton Wheel Details

As an impulse turbine, a single jet Pelton wheel or turbine shown in Figure 1 consists of three basic components.

The first (not shown) is the surrounding casing which supports the Pelton wheel and its bearings. It collects the spent fluid flow, all usually at atmospheric pressure.

The second is the rotating bucketed Pelton wheel (or runner) itself, with its Pelton double bowl-shaped buckets, each divided by a splitter to form two symmetrical jets.

The third is a stationary adjustable inlet nozzle directing the power jet, fed by a high head reservoir (currently as high as 6130 feet (1869 meters) for the world’s record holder in Switzerland). In mountain areas, where plenty of high head

Figure 2. Matthew Gass[7], of California's Hetch Hetchy Water and Power, inspecting a 47 MW, 327 rpm, 1280 ft net head Pelton wheel at the Kirkwood Powerhouse (located about 125 miles south of the goldfields where Pelton invented the wheel in 1880).

water is available, Pelton turbines are often designed with two to a maximum of six nozzles.[6]

The potential energy of the high head is converted into the kinetic energy of the atmospheric pressured jet. The impinging jet then creates an impulsive force (the sum of the pressure forces on the jet-facing bucket surfaces) to rotate the wheel, as predicted by the Second Law's Conservation of Momentum. The Pelton patented bucket design splits the jet into halves, and turns each nearly 180°, usually configured to 170°.[6] (An ideal angle of 180° to obtain a maximum impulsive force is not attainable since the exiting jet fluid must stay free of the trailing buckets.)

As Zhang[6] points out, due to the unsteady nature of the out-of-bucket flow, experiments, practical experience and general design rules have played a major role in the hydraulic design of a Pelton turbine. For instance, even the optimum number of buckets on a Pelton wheel is determined only by experience and model tests.

However, inviscid analysis[6] shows that maximum Pelton turbine efficiency occurs when the wheel speed at the pitch diameter is 0.5 (one half) of the jet velocity. In a real, viscous flow, Pelton turbines operate most efficiently when the velocity at the wheel pitch diameter is about 0.47 of the jet velocity[6]. Efficiencies of newly constructed Pelton turbine powered plants can commonly achieve about 90%.[6]

Figure 2 shows a modern day powerplant 47 MW Pelton wheel, powered by the Hetch Hetchy water system which supplies San Francisco and the Bay area. It is precision machined from a stainless-steel solid forging.[7]

Pelton Air Turbines

From their 1880 origin as a hydrodynamic turbomachine, Pelton turbines have been developed to be powered by air jets. Of course, there is a reduction in power densities, considering the 800 to 1 density difference between water and atmospheric air.

The most common Pelton air turbine that many of us have experienced is with a dental drill. Dental Pelton turbines driven by compressed air and capable of free running speeds above 300,000 rpm have been widely used for rotary cutting work in dentistry ever since their introduction in the 1950s. The Pelton wheel, contained within the head of the handpiece, typically has a diameter in the range 3.5-5.6 mm and most current designs incorporate ball race bearings. Dyson and Darvell[8] measured the performance of fourteen models of these dental Pelton air turbines. Their efficiencies were as high as 30% and power outputs were on the order of 10 W.

Where might Pelton air turbines fit into the gas turbine world? One use might be as a supplemental power unit for a jet engine oil pump, using bleed air from its compressor. So far, in queries made by me to my gas turbine associates, I've found no one who knows of the utilization of a Pelton air turbine. Perhaps a reader might enlighten me of such a use!

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Outlook on Thermal Energy Harvesting: A Pathway to Energy Decarbonization[1]

Members of the Thermal Energy Harvesting Advocacy Group of the Knowledge Center on Organic Rankine Cycle Technology (TEHAG-KCORC)

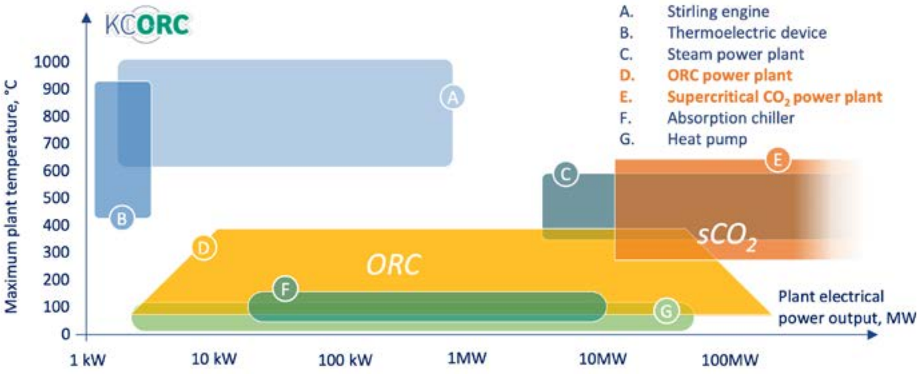

Figure 1. Range of applicability of various technologies for thermal energy harvesting

The solution or mitigation of the climate change problem demands for a complex set of behavioral transformations, concerted actions, global and continental policies, national implementations and new or improved technologies, whose ultimate goal is to avoid disastrous changes of ecosystems resulting in irreparable effects on human civilization. Such technologies also feature the important potential of creating widespread societal benefits, like more employment, more fairly distributed wealth, and significant and widespread health improvements. The amount of anthropogenic thermal energy that is dispersed into the atmosphere in any given instant by almost all industrial processes and by all mobile or stationary engines is so large that it escapes human comprehension. This waste is also a huge resource that most of the public is not aware of, possibly because it is invisible and intangible. Importantly, even in future scenarios in which fossil fuels will be displaced by other non-carbon fuels, huge amounts of thermal energy will always be generated by industrial processes and engines, as prescribed by the laws of thermodynamics.

Among the technologies that may be adopted to make use of this enormous asset (see Figure 1), one is particularly suitable for the conversion of thermal power into electrical or useful mechanical power: Organic Rankine Cycle (ORC) power plants. An ORC power plant functions according to the working principle of steam power stations (Figure 2), but instead of water, the working fluid in the closed loop is an organic substance, like so-called refrigerants, hydrocarbons, carbon dioxide, siloxanes, etc. The fluid is selected according to the temperature level at which the thermal energy source is available and its amount. Such power plants can therefore convert otherwise wasted thermal energy into electricity, making possible something an evolved human society must embrace: re-using, recovering, and avoiding waste of any kind.

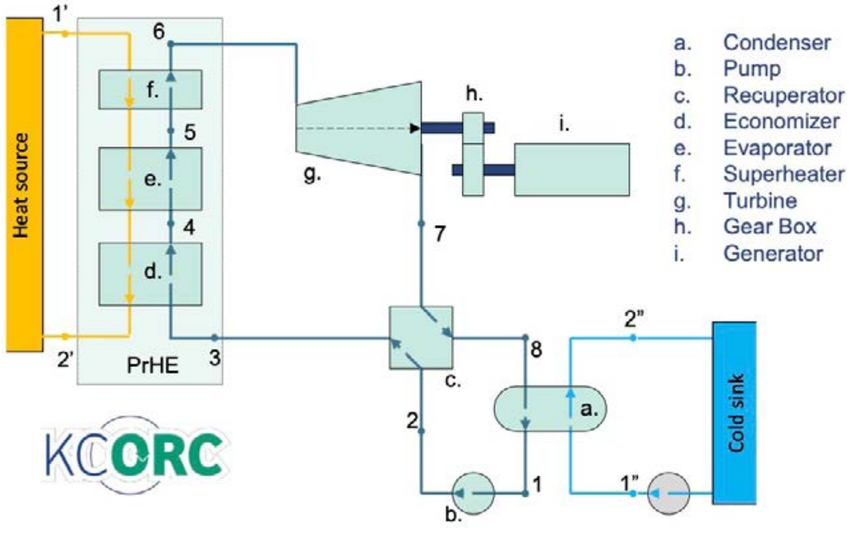

Figure 2. Simplified schematic of a typical ORC power plant

Waste-heat-to-power by means of ORC technology features many advantages. The electricity that is generated does not cause any additional emission, does not

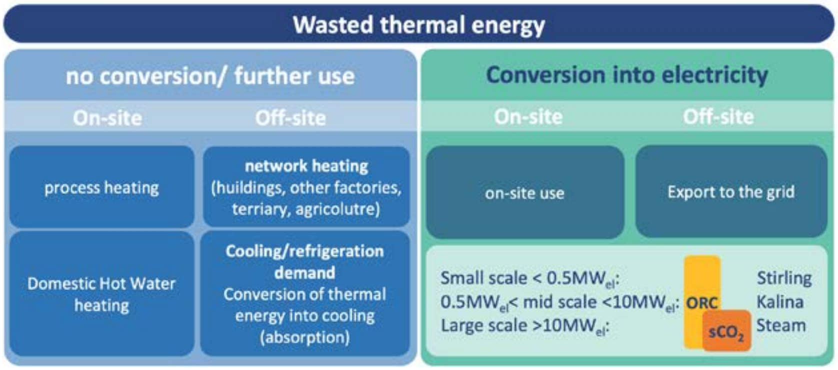

Figure 3. Rational approach to waste heat recovery in energy-intensive industry.

depend on the weather and is dispatchable. Furthermore, it can significantly contribute to reducing the dependency from fossil fuels, providing a sustainable supply of electricity that is detached from the volatility of energy markets and of the geopolitical situation in general. Electricity is more valuable than heat, much easier to distribute and key to the decarbonization of societies. Arguably, no other thermal energy harvesting technology is equally flexible because ORC systems can be used to efficiently generate power from sources of many hundreds of megawatts down to sources of just few kilowatts and at temperature levels that span the range from 100 °C to 1000 °C. The thermal energy that is released at low temperature (40 – 80 °C) can be used for heating networks, industrial usage or green houses, bringing the efficiency of the entire energy chain to almost 100%.

Worldwide, more than 70% of the primary energy consumption is lost after conversion to electric/mechanical power and half of such energy loss is available at a temperature below 100 °C. More detailed quantitative and exemplary information is provided by a study on the European scenario. According to a conservative estimate (see [1]) based on the assumption that only 50% of the thermal energy wasted from industrial processes in EU27 countries (calculated to be 980 TWh$_{th}$ in 2015) can be recovered with ORC power plants, as much as 150 TWh$_{el}$ of electricity can be generated annually. Calculations performed by KCORC indicate that the electricity generated by this CO_2-free waste-heat-to-power technology may amount to about 5% of the total electricity currently produced in EU countries.[2]

This potential of thermal energy harvesting has been evaluated based on reported data per industrial sector, per temperature level and per geographical location. The result of the analysis is that ORC technology is applicable in all countries and that 75% of the thermal energy obtained from burning primary fuels is not exploited. This energy would be available for recovery, and a large share of it could be converted into electricity by ORC power plants (see Figure 3). Moreover, many types of mobile thermal engines (truck and heavy-duty vehicle engines, ship engines, train engines and aircraft engines) inherently discard to the atmosphere from one third to half of the energy of the fuel, thus also in this case the potential is extremely large. While cars and other light duty vehicles are bound to become electric, it is easy to argue that complete electrification is impossible in the medium term, and decarbonization will be due mostly to the usage of carbon-free fuels like hydrogen. These fuels will likely be much more expensive, and this will also favor the adoption of waste heat recovery for economic reasons, as it enhances fuel economy.

It is thus clear that the potential of thermal energy harvesting technologies is enormous, but it is still largely untapped because current policies and other barriers still hinder their widespread adoption. In Europe, the so-called Green New Deal has created the context to propose amendments to the European Renewable Energy Directive and to the Energy Efficiency Directive, such that the role and value of waste-heat-to-power are properly recognized, and hopefully suitable regulation will soon be implemented in Member States in a consistent and effective way. The amendments to the directives are now in the approval process. Furthermore, the U.S. Energy Information Administration (EIA) also recently highlighted the need for reducing energy conversion losses (U.S. EIA, AEO 2022) and one should expect legislative actions similar to the ones that are being worked out in Europe.

Additional research and development activities can certainly further increase the performance and reduce the cost of ORC power systems and push their efficiency ever close to the Carnot limits. Taking again Europe as an example, in line with the principles established by the Clean Energy Transition – Technologies and Innovations Report (CETTIR) of the European Commission (2021), the creation of a proper infrastructure to boost, coordinate and evaluate research and development on thermal energy harvesting has been proposed. In analogy to what has been done for other renewable energy technologies (for example for wind energy), the creation of the European Technology & Innovation Platform on organic Rankine cycle technology has been proposed by KCORC in order to better coordinate these efforts.

For the many reasons briefly outlined, the time is ripe for the massive adoption of ORC technology for waste-heat-to-power and the support of the community of mechanical engineering professionals is a key enabler.

Footnotes

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1. This article is an excerpt and adaptation from "Thermal Energy Harvesting - The Path to Tapping into a Large CO_2-free European Power Source", Version 1, by Marco Astolfi, Marco Baresi, Jos van Buijtenen, Francesco Casella, Piero Colonna, Gilles David, Sotirios Karellas, Henrik Öhman, David Sánchez, Christoph Wieland, Davide Ziviani. Published online on 04-02-2022, freely available at **www.kcorc.org/en/committees/thermal-energy-harvesting-advocacy-group**. This white paper contains an extensive bibliography.
2. 150 TWh$_{el}$/yr of electricity is the yearly electricity consumption of more than 20 million households, or the annual electricity production of 19 nuclear plants of 1 GW capacity each, or the combined annual consumption of electricity of the Netherlands and Denmark.

Gas Turbines of the Future: Leading with Cyber Security at the Forefront

Jason Hollern, jhollern@epri.com, Electric Power Research Institute (EPRI)

Cyber security is a primary consideration for utilities in today's energy generation industry. There are several world-wide drivers that impact how cyber security is managed at the utility including: cyber security regulations, a changing threat environment, new digital technologies in power generation systems, and how the energy transformation is changing the asset mix. All these drivers are interrelated in that they all impact how utilities address cyber security challenges.

The world-wide energy transformation is driving utilities to re-examine how they generate power, how they meet their customer's and shareholder's expectations, and how they comply with changing corporate, local, and national environmental goals. Digital transformation or digitalization within the utilities, along with a shift from carbon intensive technologies to low-carbon resources can bring new cyber security challenges to the forefront. Gas turbines are a major piece of that puzzle. Gas turbine technologies will require new ways of operation and rely on new technologies for the future fleet. For example, new technologies like remote access technologies, worker aides like augmented reality and in-plant performance health monitoring, and analytical tools like digital twins (DTs) will be used. However, these tools come with additional cyber security considerations that the industry didn't address in the past; they all can create new sensitive data streams and communication pathways that could be exploited by a cyber attacker.

Gas turbines that comprise simple-cycle sites and combined-cycle sites will operate differently in the future. The number of staff onsite is expected to decrease over time as these sites become more automated, have remotely located control rooms, and rely upon vendors and integrators more to conduct maintenance and tuning. In addition, their fuel supplies may be different than today. Hydrogen blending demonstration projects are underway to determine if a mix of hydrogen and other less carbon-intensive fuel could be used to reduce carbon emissions. In addition, DT technologies, using physics-based models of components and systems to determine operational parameters and equipment health, may be used in conjunction with live operational data to help with fuel blending performance and to predict emissions. DTs are a data analytics-based models of the gas turbine using well known physical attributes to predict operating conditions, material properties, emissions, and equipment health, but could also be used by cyber security in conjunction with advanced artificial intelligence, security data streams, and correlation tools to help detect cyber security intrusions faster. For these same reasons, a DT can also provide a cyber attacker with a treasure trove of information.

To make these future states a reality, the communications within the operational technology (OT) networks and how OT network communications interface with applications and systems in the business network need to be addressed. By looking at a typical gas turbine's control system using a simplified network architecture diagram, as seen in the figure, data is created at the lowest levels in the I/O subsystems by various sensors and field devices. Data is communicated through the network using various plant protocols and is stored in the historian, a database that stores data from sensors throughout the plant. Historian data is used by plant engineers and centralized analysis centers to better understand the current state of the process control system and asset health. The logical OT boundary of a gas turbine's control network is typically a firewall or data diode represented by three brick wall icons in the figure. The historian is typically replicated across the plant's logical boundary into another historian in the control system's demilitarized zone (DMZ). The DMZ is the area that exists between a utility's corporate network and the plant's OT network. In the figure, this area is represented blow the dashed line but before the three brick wall icons. This area allows for services and the storage of data to exist outside of the plant's OT network and a method for plant and corporate personnel to access the data and services without access to the plant's OT network. This is a standard architecture used within the industry to help ensure security and integrity of plant systems.

Digital tools like DTs and centralized analysis centers are typically stored within a utility's information technology (IT) or corporate network. Those systems and applications are above the dashed line in the figure. The data is pulled from the historian located in the DMZ into the IT network.

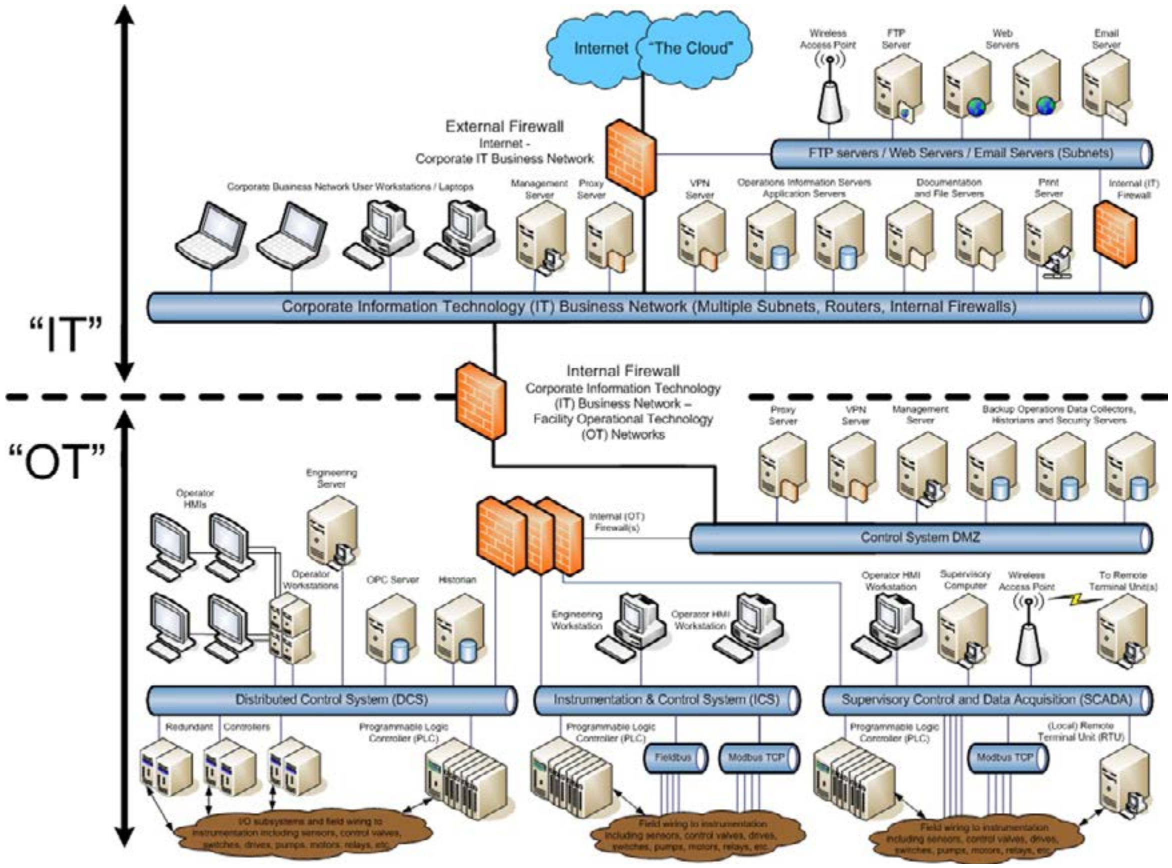

Figure 1. Generic Generation IT/OT Architecture

However, these systems are typically geographically separated. For example, a centralized analysis center that employs a DT tool may be in the Middle East, but the physical plant assets may be located in South America. The security of the generated data at the lowest levels of the OT network, and how it is stored and transported across multiple logical and physical boundaries becomes important.

The digital tools themselves, including DTs, need to be secured. In addition to being a major analytical resource, there is also a lot of intellectual property that is used to develop accurate models. If a cyber attacker were able to copy or steal a DT or alter it in a way that made the model inaccurate, damage could be done to the gas turbine. Additionally, a DT of a gas turbine can be used to devise an attack. Attackers can use a DT to gain a better understanding of the operations and vulnerabilities to devise an attack on the control system to cause damage to the asset. Digital tools that are housed in the IT network must be secured and only available to those individuals with authorized access. Other additional tools and capabilities that are needed to help address some of the industry challenges and drivers for the energy transformation should be considered, but with cyber security in mind.

There are best practices for ensuring that data, tools, and capabilities are helpful to a utility as they reach their future states for the energy transformation. These should include implementation of cyber security considerations from the beginning of the process. For example, if organizations implement new technologies and develop new communication pathways without consultation of cyber security staff, extra and costly rework may be required. In addition, utilizing a cross-functional team of IT and OT cyber security staff will help ensure that all aspects of the network architecture are considered. Ensuring that remote connections in the OT network are only allowed to authorized users and monitored to detect a cyber-attack is key to enabling the needed flexibility of having vendors, integrators, and utility staff perform work without having to physically come to site. These help to protect from a cyber attack, but detection, response and recovery controls are equally important. Organizations can prepare for a cyber attack by having a response plan and exercising the plan.

Cyber security will continue to remain a critical aspect as utilities identify their future states and how the generation fleet will look and operate. By working with cyber professionals from the onset of planning, the implementation effort for digital tools, technologies, and processes will also consider the implementation of cyber security. This will reduce the need for potential rework and redesign. Cyber security will be key as regulations, the changing threat environment, and new digital technologies in power generation systems and processes adapt to enable an energy transformation. As cyber security challenges continue to evolve and progress, having a close relationship with the cyber security teams will become more important.

Award Recipients

Congratulations to all award recipients and thank you to all ASME IGTI committee award representatives whose work assists the awards and honors chair and the awards committee in the recognition of important gas turbine technological achievements. Thank you to William T. Cousins for serving as the IGTI Honors and Awards Committee Chair, John Gülen as Industrial Gas Turbine Technology Award Committee Chair, and Wilfried Visser as the Aircraft Engine Technology Award Committee Chair.

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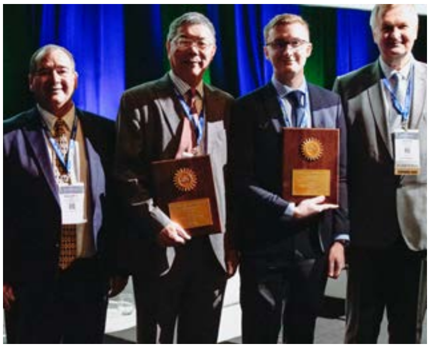

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2022 Industrial Gas Turbine Technology Award

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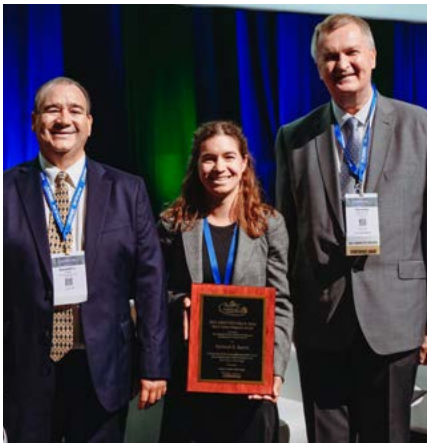

2022 Dilip R. Ballal Early Career Award

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Upcoming Award Opportunities

2023 ASME IGTI Scholar Award

Nominations due to igtiawards@asme.org by

SEPTEMBER 1, 2022

2023 ASME IGTI Aircraft Engine Technology and Industrial Gas Turbine Technology Awards

Nominations due to igtiawards@asme.org by

OCTOBER 15, 2022

2023 Student Scholarships

Application process opens at asme.org/asme-programs/students-and-faculty/scholarships in

DECEMBER 2022

ASME IGTI Division Executive Committee and ASME Gas Turbine Technology Group

Appoint New Members

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Jaroslaw Szwedowicz
Siemens Energy AG

The ASME Gas Turbine Technology Group (GTTG) Welcomes New Members

The GTTG is pleased to announce the appointment of Dr. Sean Bradshaw, Pratt & Whitney, as the 2022 – 2023 GTTG Chair. Dr. Bradshaw welcomes three new technology group members: Sina Stapelfeldt, Imperial College; Peter Stuttaford, Thomassen Energy; and Liping Wang, GE Global Research Center.

Sina Stapelfeldt
PhD Mechanical Engineering, Rolls-Royce Vibration University Technology Centre, Imperial College London

Peter Stuttaford, PhD
Chief Executive Officer Thomassen Energy

Liping Wang
Technology Manager, Probabilistics Lab, GE Global Research Center