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M. RUSSELL and **B. BAILIE,**
Siemens, Houston, Texas

How APM in LNG operations can lower TCO and boost ROI

As the world's hydrocarbon appetite continues its rapid turn toward lighter fare (e.g., natural gas for power generation, transportation and industry), massive, near-term investments in global, capital-intensive, fully digitalized LNG infrastructure are needed. According to Shell's *LNG Outlook 2018,* natural gas demand is forecast to rise twice as fast as growth in total global energy demand through 2035, with LNG leading the way with forecast growth of 4%/yr.

Despite encouraging prospects for LNG, final investment decisions (FIDs) on new infrastructure stalled between 2015 and 2017 due to global oversupply, which is expected to continue into the early 2020s.[1] Since LNG projects have 4 yr–5-yr build cycles, FIDs are expected to restart this year.

What can help make LNG FIDs more compelling for investors? The answer is to focus less on minimizing the infrastructure's upfront capital costs and more on lowering the long-term total cost of ownership (TCO) over the expected 30-yr lifecycles of that infrastructure. The latter will eventually dwarf the former by more than 10 times.

Understandably, investors must have assurances that the engineering, procurement and construction (EPC) phases of their complexes (e.g., LNG terminals, liquefaction trains, regasification facilities, etc.) are on time and on budget, and that they lead to successful commissionings and startups. They need to know that revenue-generating outputs will start and continue as quickly, efficiently, reliably and safely as possible. This allows investors to recover their invested capital sooner, and then enjoy maximum operating margins for the infrastructure's remaining lifecycle.

For all these reasons, investors—and the EPC companies serving them—must consider the fast-evolving role that digitalization can play in more fully integrated operations and asset performance management (APM). Both are keys to faster returns of invested capital, higher long-term operating margins and lower TCO.

According to a joint report from McKinsey & Co. and Accenture on the oil and gas industry's adoption of digital strategies, operators will spend approximately $80 B over the next 2 yr on operational efficiency that, if invested in digital technologies, could lower operational expenses by 25%, boost field recovery rates by 8%; and result in a sustained profitability increase of 11%.

The authors' experience in digitalization of operations along the entire value chain—upstream, midstream, downstream and distribution—suggests that these figures may be conservative. What we do know is that full, end-to-end digitalization can produce both incremental and quantum improvements in asset operational performance (**FIG. 1**). While digitalization may provide competitive advantages for LNG operators, it will be a competitive imperative for them in the future.

LNG digitalization for long-term operations. What does digitalization in the operations of LNG facilities look like? Let us start by defining digitalization itself. For the LNG industry, the term is described as the harnessing and analysis of real-time and historical data, as well as the asset design data, to provide the decision support to optimize the overall performance through improved reliability and integrated operations management throughout the lifecycle of the asset.

It also helps to understand what digitalization solutions are not. They are not one-off, digital point solutions deployed to speed up one particular process, with little or no regard for the asset as a whole. They are not original equipment manufacturer (OEM) data silos that collect digital data but limit information sharing, which can undermine or inhibit otherwise well-informed decision making. They are not data recording, transcription or reporting with any manual intervention, which can add hours, days or weeks of latencies to their cycles—not to mention the inevitable errors that can be propagated forward, if not compounded, with additional data.

Digital technology has been evolving continuously in the oil and gas industry since the first microprocessor-based digital control systems debuted in the early 1980s. The internet dot-com boom in the late 1990s raised many expectations about game-changing applications, but it is only now that we are seeing the exponential growth of digitalization—referred to as Industry 4.0. However, process industries, particularly the oil and gas sector, have been slower than others to adopt new technologies.

FIG. 1. End-to-end digitalization can produce both incremental and quantum improvements in the operational performance of LNG assets.

This slow adoption has valid reasons, such as the industry's high priority for safety and using well-proven technologies to avoid costly production disruptions. LNG plants are designed for continuous operations with minimum time for planned shutdowns, making it both difficult and potentially expensive to make any changes to the asset, including adding new sensors. Another barrier to adopting digitalization is that the operators have traditionally been sensitive to sharing performance data—even with their OEM data, and even if the data had no operational significance or relation to intellectual property.

Nonetheless, the LNG industry can benefit from embracing an end-to-end digital strategy to optimize long-term operations, using these proven technologies in LNG facilities:

- **Low-cost, smart sensors.** Digital applications can exploit the development of low-cost, smart sensors. Sensors can give an LNG facility's equipment baseline performance "signatures" that enable real-time monitoring and analysis of any operating data anomalies. Enhanced measurements can improve availability via more accurate predictive diagnostics.
- **Robust connectivity to cloud infrastructures.** Affordable, secure links to global, scalable, cloud-based computing and storage resources on a pay-as-you-go basis lowers entry costs and simplifies application deployments for LNG operations. Global standards (e.g., OPC Unified Architecture) facilitate machine-to-machine communication. This reduces, if not eliminates, proprietary lock-ins on how equipment talks to other systems. New and legacy infrastructures can exchange information, helping extend the utility of older equipment and the value of the legacy investments in it.
- **Advanced data analytics.** The data science behind advanced analytics includes sophisticated statistical models that seek patterns in data at speeds far beyond even the smartest human's ability to discern them. The use of advanced analytics has traditionally been constrained by the cost and access to the required computer capability, but cloud computing has made this power—including supercomputer parallel processing—much more accessible, affordable and quickly scalable.
- **Artificial intelligence (AI) and machine learning.** AI is the application of computer technology to perform tasks that would usually require human intelligence and cognition. Machine learning is an AI application that runs data through sophisticated statistical models to find patterns and, in effect, to learn from the data and adapt its functions without specific programming. The more data that is processed, the smarter the program or machine becomes.
- **Digital twins of physical assets.** With computer-aided design (CAD), engineering and manufacturing software, it is possible to integrate all asset data to build a virtual representation (i.e., a digital twin) of an asset—

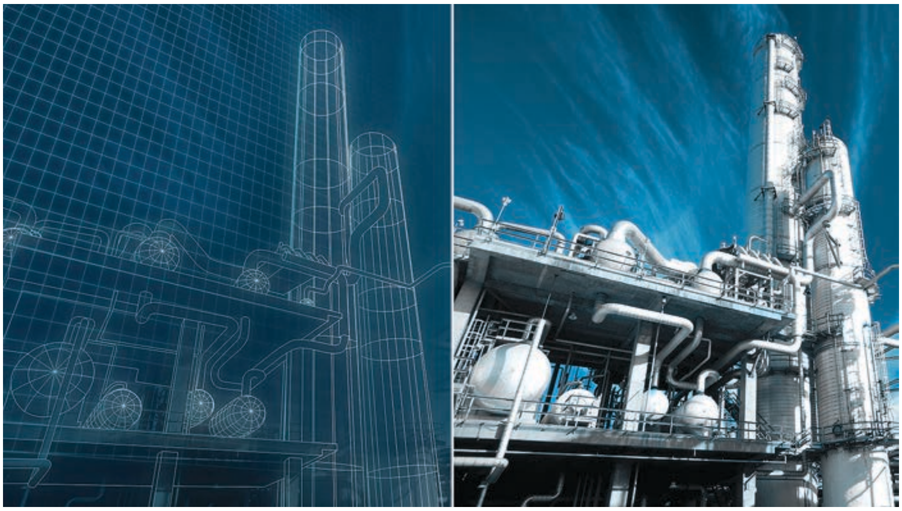

FIG. 2. With CAD, engineering and manufacturing software, it is now possible to integrate all asset data to build a digital twin of an asset.

FIG. 3. The world's first all-electric LNG plant uses APM and enhanced drive-train analytics to reduce downtime, lower maintenance costs and increase availability.

from conceptual design through detailed design, fabrication, construction, commissioning and operations (**FIG. 2**). For greenfield projects, the digital twin can be used to minimize capital cost by effectively comparing design options. It can also be used to reduce cycle times and engineering efforts. In the operational phase, including brownfield deployments, the digital twin provides the ability to compare operations to design conditions and quickly conduct "what if" scenarios without the risks of costly disruptions or expensive physical modeling.

- **Cyber security protections.** Cyber security standards and layered, defense-in-depth models have grown in response to the ever-increasing frequency and sophistication of cyber threats that continue to threaten critical infrastructure, especially energy. Safeguards include ISA/IEC 62443, along with ISO 27001 and 27002—the world's foremost data security standards. Additionally, new protections against advanced, persistent threats use small, kilobit-sized embedded software agents to monitor networks for behavior changes that can signal a possible intrusion.

LNG digitalization for asset performance management. In an LNG context, APM refers to the use of processes, systems and technologies to optimize the efficiency, productivity, reliability and availability of an LNG facility. APM helps maximize asset utilization and output, lower operational expenditure (OPEX) and TCO, and minimize the risk of disruption. APM applications supported by digitalization include condition monitoring, predictive maintenance, asset integrity, quality management and, importantly, health, safety and environment (HSE) management.

At the core of how digitalization can improve APM are advanced analytics using AI and machine learning. With real-time and historical data for AI, LNG facility operators can employ this technology to look for signs of anomalous machine behaviors in individual pieces of equipment—for example, comparing a bearing's vibration signature over time or analyzing other systems, such as the performance of a refrigeration compression train. This equipment health analysis provides the basis to conduct prescriptive maintenance.

Across the asset, AI can be used to optimize the performance of compressors, drive trains, heat exchangers, power equipment and all mission-critical assets that are core to the operations of LNG facilities. This operation can be done remotely via secure communications links and cloud-based technologies.

For example, Europe's first LNG plant near the Arctic Circle, which was also Europe's first all-electric LNG plant (**FIG. 3**), installed six compressor trains. For this application, the authors' company developed a special sensor that detects minute quantities of dust generated in the equipment and uses this measure as one of the key indicators for prescriptive maintenance. This facility uses APM and enhanced drive-train analytics to:

- Reduce time for maintenance and stoppages by approximately 20%
- Lower the direct costs of maintenance and downtime
- Increase availability by reducing planned and unplanned stops.

Specific to compressor performance, the authors have found that, by averting trips and resulting forced outages via early detection of potential faults and preventive remediation, compressor availability can increase as much as 3%—approximately 11 d/yr.

Extrapolated over a compressor's decades-long lifespan, this additional availability provides significant cost avoidance by saving disruptive downtime and related expense. These savings not only apply to compressors but also to ancillary equipment, even valves, as unplanned shutdowns can often result from their failures. Taking a holistic approach and applying prescriptive diagnostics to the equipment in the plant asset are the best strategies to optimize operations overall.

Another APM benefit is extended lifecycles of hardware components with more proactive and tailored maintenance approaches. For example, condition-based maintenance (vs. scheduled maintenance) provides maintenance when equipment needs it and is done during planned outages. This can also optimize spare parts inventories, freeing otherwise constrained capital.

Taking the next steps. Existing LNG facilities are advised to take a two-phased approach to digitally driven APM. First, operators should conduct a health assessment of their facility, including its electrical, instrumentation and control capabilities and functionalities. Second, given these findings, they should develop a plan for the upgrades, enhancements and integrations of the sensors, equipment and systems required to close gaps and boost overall APM across the plant.

Before implementation, organizational implications should be addressed. Staff may need training in the new technologies. Meanwhile, organizational silos, such as the gap between operational technology (OT) and informational technology (IT) teams, may need to be identified, and steps may need to be taken to ensure a greater understanding of the technologies' contributions and to facilitate collaboration between these teams.

Integrated operations and a digitally driven APM strategy are key to the future of LNG plant operations. They can help to deliver faster returns on invested capital, higher long-term operating margins and lower TCO—all compelling economic benefits for LNG facility investors. Their EPC companies—which typically design, build and commission these complex assets—can also benefit by including the advantages of integrated operations and digitally driven APM in their value propositions and competitive differentiations. HP

BRUCE BAILIE is the Digital Officer for Siemens' oil and gas vertical, Americas region. He brings extensive, cross-vertical experience in process industries, including oil and gas, with a particular focus on software solutions. His responsibilities include drawing on a broad portfolio to deliver integrated solutions tailored to the given needs of oil and gas customers. These solutions encompass dynamic process simulation and optimization; monitoring of high-speed equipment and associated data analytics; and the integration of ERP systems to enhance business processes.

MATTHEW T. RUSSELL is Vice President, Gas-to-Power, LNG for Siemens' Power and Gas Business. He is responsible for Siemens' global LNG portfolio inclusive of strategy, business development and captive finance. Mr. Russell joined Siemens in 2017 following a 10-yr career at KBR. Mr. Russell earned a bachelor's degree in civil engineering from Ohio State University in 2003, and received a master's degree in business from the University of Delaware in 2007.