Think smart, pump smart

Edward Fowler and Troy Salazar, Siemens Oil & Gas, USA, address the keys to enhancing pump station performance and long-term investment returns.

As oil and gas pipeline operators know, capital investments in building transmission infrastructure are eventually dwarfed by the long-term operating expenses of those assets. One of their biggest costs is utility-sourced power for the pumping stations that move customer oil, gas, and NGL products through the length of their pipelines. Of course, other costs, such as maintenance and repairs, also add up over the several decades of a typical pipeline's lifecycle.

Inside pipeline pump stations are power-hungry reciprocating and centrifugal compressors. While some of these giant machines may use fuel drawn from the pipelines, most are driven by large electric motors able to generate up to several thousands of horsepower each. It is thus little wonder that their energy costs can be among the largest expenses for pipeline operators, month after month.

In fact, just one pump station can draw many megawatts a year in electricity, adding up to many millions in utility costs over the length of a particular pipeline and including all its pumping stations. For example, in the use case of an 800 mile pipeline with 18 pump stations, electricity costing US$0.075/kWh can total US$150 million in utility expenses over five years.

The challenges of operational variability

Another big issue is tracking and analysing pump station expenses, efficiencies and utilisation across different pumping stations. This can be difficult because of variability in their local topography, local utility rates, number of pumps, and batch loads. While pipeline owners presumably negotiate the best wholesale power rates available from local utilities along the pipeline, each pump station's efficiency and utility ratchet charges can affect a pipeline's overall operating costs.

Comparing pump station operating profiles can vary for another reason too: many were built using the common procurement practice of sourcing pumping components and equipment from diverse, often lowest-cost suppliers, in order to minimise initial capital expenses.

Not only does this ignore the cumulative, long-term operating expenses and total cost of ownership, but using different vendors requires much more integration of their products and co-ordination of their support after installation and during their products' lifecycles. It also increases sparing costs and complicates training, maintenance and repairs. All of this can add up to millions of dollars in direct and indirect costs over the decades this equipment is expected to operate.

Pipelines 4.0

Pipelines 4.0 is a turnkey, single-source approach to the provisioning and operation of rotating equipment that combines fully integrated and pre-tested hardware (and associated peripherals and controls) for pipeline pumping and compressor stations with data analytics, lifecycle services, and cybersecurity. It tames complexity to cut the time, costs, and risks of bringing next-generation pipeline capacity online. It builds on the extensive pipeline experience, breadth of product portfolio, and rich domain expertise in rotating equipment, electrification, automation, and digitalisation that Siemens brings to the oil and gas industry worldwide.

Pumping smarter via advanced analytics, artificial intelligence, and machine learning

Today, these challenges are being addressed with a practical and economical, data-driven approach toward asset utilisation called SmartPumping, an offering from the Siemens Pipelines 4.0 platform portfolio.

For operators across North America, Europe, the Middle East, and elsewhere in the world, this model can potentially reduce their utility charges, while gaining many other advantages. Those include reducing pressure transients, improving the consistency of flowrates, maximising pump-system efficiency, and optimising pump maintenance. By applying sophisticated software technologies – including advanced analytics, artificial intelligence, and machine learning – they can enhance and optimise load management, power consumption, and batch scheduling across all their pumping stations.

Inevitably, power consumption at each pump station differs depending on load requirements, such as the number of pumps – with much smaller amounts consumed by their peripheral equipment. A large variable is the product batch type moving through the pipeline, whether raw hydrocarbons or various refinery feedstocks. Their distinct densities, viscosities, and interrelated hydrodynamics can all affect power usage due to the different physical loads they impose on pumps.

This type of asset performance management and utilisation solution is not only applicable for greenfield applications. Since they are control-system agnostic, they can also complement, even leverage, the extensive monitoring and control capabilities that pipeline operators may have already in place to ensure even more efficient and reliable operations. After all, existing pipeline operations already generate vast amounts of data; the key is making better use of that data to improve efficiency, reliability, visibility and, ultimately, safety.

For example, the automation and SCADA systems at one of North America's largest pipelines sends more than 20 000 points of data every five seconds from scores of pump, valve, and monitoring stations along the length of the pipeline. The data is transmitted securely to the company's control centre via satellite and cellular communications.

At that point, SmartPumping technologies can process the data by rapidly analysing it against the delivery schedules of various customer products, each with its own hydraulic characteristics. The solution would then propose parameters that take into account the power demands of the hydraulic characteristics of each product.

Real-time decision support for batch optimisation

SmartPumping works by recommending a range of highly optimised pump station parameters to control room operators and planners. Those are based on the transmission delivery schedules of customers, as well as utility costs, environmental conditions and actual product throughput.

The solution employs software hosted in the cloud-based Siemens MindSphere Internet of Things (IoT) operating system. MindSphere is designed for industry and complies with the world's strictest cybersecurity standards used by governments, military, banks, and other industrial sectors that involve critical infrastructure.

SmartPumping is cloud-hosted and therefore provides a software-as-a-service, pay-as-you-go subscription model. This eliminates upfront capital expense or commissioning costs. It also enables deployments in 1 - 2 weeks (vs months) and provides scalability for any size pipeline operation.

In effect, pipeline operators gain more operational and scheduling intelligence for batch optimisation. With this capability, they can finely tune each station's power consumption and pump performance to the specific needs of the various batches of products moving through their pipelines. It can help them avoid ratchet surcharges that come with excessive spikes and peak-power use. It can also prevent pump motors from drawing unneeded power.

With enhanced decision support, operators can:

- Leverage electric utility price differentials between pump stations – shifting either downstream or upstream some of the power load of one pumping station that is subject to relatively expensive utility rates, to another pump station where utility charges are less.
- Schedule batches based on utility rates during off-peak hours, avoiding the cost penalties of electric utility ratchet charges that during peak hours can soar to 2 - 5× more expensive than standard rates.
- Ease mechanical stresses on their systems – such as wear and tear on the pumps, seals, bearings, valves and other moving parts – by reducing or eliminating surge effects with dynamic and predictive tuning of pumping pressures relative to the types of fluid materials and environmental conditions affecting densities and viscosities.
- Cut carbon emissions – helping to boost an operator's reputation for environmental concerns, if not also providing potential carbon offset credits to sell. In the use case example, a 1% reduction in power usage can translate to 70 000 t of CO_2 savings.

Batch optimisation requires an intelligent sensing fabric connecting the pump station motor controls with its pipeline's contents. While the products may be constantly changing, they are sequential and predictable nonetheless. That is because operators know which batches are moving through the pipeline at any one time and at any one location. Also, with ultrasonic process instrumentation, operators and their automation control systems can have real-time data about products in the pipeline, such as density, viscosity, flow and other characteristics.

This data can enable control rooms to activate only the number of pumps required to keep the product moving at its specified flowrate but without exceeding the pipeline's allowable pressure limits. And, for those pumps that are needed, variable frequency drives are used to adjust their motor speeds, drawing only the power the pumps need.

If operators can trim even a small percentage from their energy costs by optimising the power utilisation in their pumping stations, they could boost profitability dramatically. In the use case previously mentioned, a conservative single percentage point reduction in power by each of the 18 pumping stations along the pipeline's route can save US$7.5 million in the first five years.

Two key components

One key component of the solution is a utility contract model. It simplifies the process of incorporating the terms of power purchase agreements with multiple utilities and associating those pricing models with the assets that draw power under each agreement.

Another key component is a sophisticated hydraulic model that is configurable to virtually any pipeline design. When combined with utility price information and

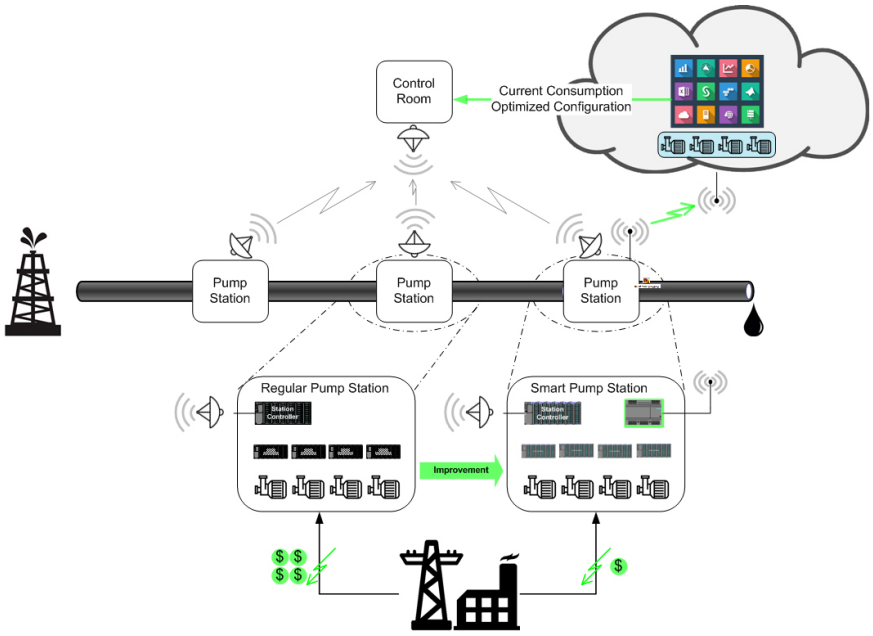

Figure 1. Each pump station communicates its real-time operating data over secure links to both the pipeline control room and the Siemens SmartPumping solution hosted in the Siemens MindSphere cloud at the upper right of this diagram. The latter returns constantly updated operating recommendations based on pipeline products in transmission, environmental conditions, utility rates, and other factors.

product transmission schedules, operators have detailed guidance on how to best operate their pipeline assets.

Both models take advantage of advanced analytics and artificial intelligence to make the solution algorithms even smarter over time. In a process called machine learning, the algorithms continually refine their recommendations, adjusting them to new conditions in real-time using the data that is continuously received from the pump stations as the 'fuel' to make those refinements.

Furthermore, the solution delivers asset and utility level data analysis to help operators negotiate power contracts when they are due for renewal. By lowering negotiated contract rates using insightful analyses of historical data, operators can increase their utility cost savings even more.

For mid-tier and smaller pipeline operators, this capability can address their typical lack of expertise and staff dedicated to power optimisation and utility contract negotiations. Often, they use consultants and in-house models to help manage those costs, but rarely, if ever, are their optimisation efforts done in real time. Instead, it can take several days or weeks for data to be processed and analysed, before decisions can be made based on the derived operating insights.

For operators of all sizes, both the utility contract model and the hydraulic model in combination give their planners the means to input product delivery schedules and throughput targets. Based on analytics of real-time data rollups from field-level systems, the tool offers minute-by-minute recommendations of optimal settings for pumps and valves.

From a workflow perspective, the solution follows these steps:

- Measure: acquire parameter data from sensors at pumps and environment in each pump station.
- Aggregate: perform mathematical operations using edge computing to reduce bandwidth and rate.
- Upload: communicate the data using a rugged, industrial-grade IoT gateway via highly secure wireless links into the equally secure MindSphere cloud-based IoT operating system environment.
- Store: keep data securely in the cloud to allow future use cases and further processing of the data.
- Optimise: map field data and run optimisation to compute an optimal configuration for pipeline products, using sophisticated algorithms made ever-smarter by AI-driven machine learning.
- Apply: deliver optimisation recommendations to the pipeline control room operators.

Enabling the digital twin concept for faster commissioning

Software simulators can also be used to validate and test automation software before being installed in a pump station's control systems. In addition, with the mechanical, electrical, physical and other systems all designed with digital modelling software, it is possible to use convergent modelling of these individual models to, in effect, create a 'digital twin' of each pump station.

Planners can use these digital twins to try out innovative approaches to further reduce operating expenses with no risk or cost. Day to day, digital twin models can also be used to lower engineering, testing and commissioning time, and costs of upgrading pump stations to enhance performance.

For example, when a digital twin is used in the deployment of a SmartPumping solution, pump station automation software can be 100% tested before installation. This pre-testing can lower start-up costs considerably, accelerate the commissioning and overall project schedules, and increase reliability.

Condition monitoring and condition-based maintenance

By transforming pipeline pumping data into smart data, midstream operators can boost the real-time functioning visibility of their pump stations. In turn, control room technicians can drill down further to monitor a pumping station's equipment performance more closely and set operating alerts should key parameters be exceeded.

These alerts can trigger prescriptive or preventive maintenance before problems occur that could disrupt the pumping station's operations or, worse, endanger the environment or personnel safety.

It is also possible to tie-in the data to a conditioning monitoring maintenance programme that only services equipment when its performance degrades, indicating maintenance is needed. This approach can save costly dispatches of technicians for routine scheduled maintenance, which equipment might not require. It can also save on spare parts, enabling a reduction in spare part inventories with a shift to just-in-time part deliveries.

Ultimately lower total cost of ownership and maximised asset utilisation

Enhanced, next-generation digital capabilities, such as batch optimisation via SmartPumping to lower utility costs, can help increase the profitability of pipelines over their entire lifecycles. In addition, the power savings can help shrink an operator's carbon footprint and enhance their reputation for environmental stewardship.

Even during construction, simplifying deployment and subsequent operating complexities can cut project risks dramatically, while reducing total cost of ownership over a pumping station's expected decades-long lifecycle. Add to that the benefits of increased operating visibility and predictive, condition-based maintenance – both of which can help provide extra measures of reliability and safety.

To stay competitive and ensure maximum asset utilisation, midstream pipeline operators need to increase the integration and digitalisation of their operations. Over time, the value of highly integrated, data-driven pumping solutions will become ever more apparent and indispensable.