

Pipeline Operations Optimization: Key Opportunities for Smart Technologies

Industrial IoT devices and other technologies can help cut costs, ease compliance and enhance safety across pipeline operations

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Hydrocarbon pipeline operators face their highest levels of public and regulatory pressure to date, while also being expected to increase efficiency, enhance public safety and worker safety, and deliver higher returns for shareholders.

Smart technologies, including Industrial IoT devices, cloud computing and intelligent software, hold tremendous promise to help operators manage these demands. The technologies are available today, and are already helping manufacturing and industrial companies meet similar demands.

In pipeline operations, forward-thinking operators are beginning to identify the best practices of applying smart technologies. These best practices include:

- Quality data
- Energy optimization
- Root-cause analysis
- Predictive monitoring
- Condition-based maintenance

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SOLVE.



Quality Data

Just as big data is the key to many improvements in our daily lives, such as the driving directions on our smartphones, it's also key to improving pipeline operations.

In pipeline applications, big data can include:

- Data on all possible operating process parameters, including drive train, pumps or compressors, temperatures, pressures and flow rates.
- Data on all possible instrumentation parameters, including meters, transmitters and analytical tools such as gas chromatographs.
- Historical data, including:
 - Short-term data collected at frequent intervals for incident investigations.
 - Long-term data collected at less frequent intervals for comparative analysis and identification of trends.
 - Event data, such as equipment failures and human intervention on the pipeline equipment for replacements and preventive maintenance.

However, big data can be too much data. That's why pipeline operators need to manage it to access only quality data, which is the underpinning of all analytical solutions for optimizing pipeline safety and operation. But there are pipeline-specific challenges related to the collection of this "good" data, such as:

- Identification and retention of the validity of data collected; for example: are the pressure transmitter, the PLC and the data-collection equipment all operating correctly, and is the pressure transmitter connected to the operating pipeline, or is it isolated for some reason.
- Centralization of data for analysis and archiving, especially given the low-bandwidth communications used on remote pipeline sites.
- Verifying that data collection is highly reliable and available: analysis is difficult when the available data contains gaps.

Accessing Data for Optimization

It is important that the expansion of data collection, beyond what is directly required for pipeline control systems and the operators of these systems, provides a basis for optimization. For example, many transmitters and other devices have evolved from strictly providing process parameters to providing many pieces of information regarding device health and operation.

The key challenge of collecting extra data: regulatory bodies have recognized that presenting correct and accurate data to operators is a critical requirement for prompt and effective actions during an emergency. In some places, pipeline operators are legally required to test all components, from the transmitter to the SCADA system, each time a change occurs in the transmitter, the SCADA system or any device or system in between.

Typically, SCADA systems have been used as a source for historical data. However, to reduce end-to-end testing, pipeline operators are now moving to the independent collection of historical data. This means only the data required by operators is sent to the SCADA system.

Consolidation can include:

- Sending data at a lower resolution (larger time interval).
- Using modern, real-time data historians that provide sophisticated ways of compressing the data, recording it and varying the data from an established pattern. This includes reporting values when they have changed from the last reported value by a configured percentage or amount, and also monitoring for change from the trend established by pre-existing values and other data compression algorithms.

One solution to the independent collection of historical data is to collect it locally at each pipeline station. The data is then forwarded to a central repository without passing through the SCADA system or station HMI. The advantage to this is data may be collected and stored locally at a high rate of speed, and consolidated data may then be sent to the central repository.

Moving Data to the Cloud

The location of the central repository for historical data is also evolving. Traditionally, the data was stored at a central location associated with the SCADA-system servers. Migration of these central, operator-managed repositories to cloud-based repositories managed by an independent, cloud-operating company is becoming more popular due to the following:

- Cyber security of the data stored in the cloud is typically improved. Pipeline companies are choosing to stick to their business of safely and effectively shipping hydrocarbons, leaving management and security of cyber-repositories to companies focused on that business.
- Access to the data for analysis is more efficient in the cloud. Providers of analytics tools can access the data directly, without requiring access to the operator's internal networks and computer systems.
- Data preservation is a key goal of cloud providers. With the criticality of long-term retention of data for analytics, this is a very central issue to pipeline operators.
- Unidirectional security gateways may be employed to move the data from the control system to the cloud repository, helping to maintain safety of the control system.

Data Analysis

Once data is collected and validated, the pipeline operator can use data analysis to begin optimizing pipeline equipment and operations.

The calibration of transmitters, meters, gas chromatographs and other instruments measuring the pipeline operations play an important role in helping to confirm data validity. Cybernetic analysis can be brought to bear at this level to minimize the calibration work necessary while still maximizing data accuracy:

- Instruments with a high level of built-in intelligence will monitor their own operation and may be able to directly report when calibration is required. This requires not only the use of a modern instrument, but also the collection and processing of the non-process related data from the instrument.
- In other cases, analysis of historical non-process data from an instrument may be used to predict when physical calibration is required. Again, the collection and processing of the non-process-related data is required.

In both these cases, the calibration exercise is performed only when necessary and is no longer a calendar-based exercise. Calibration moves from scheduled preventive maintenance to condition-based preventive maintenance. This can have safety implications, such as by reducing the need for workers to drive to sites and work on equipment, and reduce unnecessary production interruptions, while also cutting costs.



Level	Description	Analysis
5	Future Cybernetic Analysis	<ul style="list-style-type: none"> Artificial intelligence Predictive analysis applied to leak detection Real-time tuning based on predictive analysis
4	Cybernetic Analysis	<ul style="list-style-type: none"> Predictive analysis Condition based maintenance
3	Human Analysis	<ul style="list-style-type: none"> Energy optimization Root cause analysis
2	Comprehensive Data	<ul style="list-style-type: none"> Historical data not required for day-to-day operations is available Historical data has high availability and reliability Standardized, equipment-based data
1	Operational Data Only	<ul style="list-style-type: none"> Historical data is limited to that required for day-to-day operations Historical data has intermittent availability and may be unreliable Non-standard, sensor-based data

Energy Optimization

Energy is the largest operating cost for pipeline companies. Anything that can be done to reduce energy usage while maintaining throughput can directly impact the bottom line. Reduced energy consumption also provides pipeline operators with positive external market messages about reducing greenhouse gases and can help reduce their carbon taxes.

In pipeline applications, most energy consumption comes from the drive trains used to turn the pumps or compressors that push the liquids or gas through the pipeline. In many cases, particularly in remote areas where large supplies of electricity from the grid are unavailable, the drive train runs off the product passing through the pipeline. Most recently, the trend has changed, from natural gas or diesel engines to motors powered by electricity. This has transferred concerns about greenhouse gas emissions from the pipeline company to the electric utility or electricity producer.

One of the simplest, yet very common, power-consumption issues is that of fixed-speed electrical motors. The AC motors in these systems consume more power than necessary because they drive the pump or compressor at a fixed speed that is often above what's required. This results in excessive pressure and flow rates that are typically mitigated by recirculation within the station, wasting energy and causing more wear and tear than necessary on the station equipment. Stations where these issues most commonly arise are typically older stations, designed before the common use of variable frequency drives.

Stations where these issues most commonly arise are typically older stations, designed before the common use of variable frequency drives (VFDs). This can be easily addressed by retrofitting the station with VFDs.

Measuring and Optimizing

The first step in optimizing energy usage on pipeline equipment is to measure the amount of energy being used. This can be done by measuring fuel gas flow into the gas generator or electrical usage by individual motors. Typically, electricity measurements are done on a station-by-station basis, making it difficult to identify an individual motor's power



consumption, particularly in stations with several separate pumps or compressors. The installation of additional power meters on a per-pump basis can provide the necessary information to analyze power optimization opportunities.

Optimizing energy usage beyond confirming the drive trains are optimally running requires attention to the actual process, or operation of the pipeline. Optimization in these areas can include:

- Using a drag-reducing agent (DRA) to reduce friction in liquid pipelines. DRA usage can be optimized based on location, flow rates and product in the pipe.
- Operating the pipeline to make sure higher flow rates, which require more energy, are used during off-peak hours, when electricity is less expensive, while lower flow rates are used during peak hours.
- Peak shaving and load shifting using large-scale energy storage.

Root-cause analysis

When an issue occurs on a pipeline, operators conduct root-cause analysis to identify why the event occurred and drive actions to help prevent or mitigate recurrence. Relying on human memory and intuition for root-cause analysis is unreliable. In many cases, no human witnessed the event or no visible evidence may be available.

Evidence-based analysis is key. Good historical data allows for unbiased analysis and identification of causal factors. Actions arising out of root-cause analysis may include monitoring of certain conditions to provide early warning of a repeat event: a rudimentary form of predictive monitoring.

Event management

The Industrial IoT can bring together root-cause analysis data from a myriad of sources, including maintenance systems, SCADA systems, historical data and calibration data. Once root causes have been identified and corrective actions have been planned, the actions can also be recorded and associated with the data supporting the analysis. A record of the actions being completed, such as in the maintenance system, and the subsequent collection of historical data can provide a complete record of an event and its systematic resolution.

Predictive Monitoring

Predictive monitoring allows pipeline operators to identify signs of upcoming events prior to their occurrence. With this knowledge, they may be able to take actions to mitigate an event before it occurs. For example, replacing a faulty valve before it damages a compressor is vastly less expensive than if the issue had gone unnoticed and required an overhaul of the compressor. Alternately, simply knowing a piece of equipment is going to fail ahead of time might allow for replacement planning, rather than replacement being required without notice.

Predictive monitoring has two steps:

1. Identifying a pattern in historical data, which indicates that an event will occur at some point in the future.
2. Monitoring real-time data for the identified pattern to provide the prediction of the event.



Humans can identify simple and dramatic patterns using trending and historical-analysis tools. At the same time, pipeline systems can be very complex. They are interrelated in a myriad of ways that are not necessarily intuitive. For example, a gas turbine at a compressor station may be impacted by the air-intake system, air-filtering system, exhaust system, lubrication system, fuel gas system and many others. Thus, it can be either difficult or impossible for humans to detect small pattern changes from normal operations in one or more different pieces of data.

Better results can be obtained by employing mathematical models for predictive analytics or machine learning, which examine large quantities of data for mathematical deviations from normal operation that occurs prior to the event. These models use statistical methods to examine data and determine if changes in that data can be correlated with the event. The advent of the Industrial IoT, cloud-based computing and cloud-based storage of historical data has very recently driven the development of these model-based predictive maintenance tools.

In addition to identifying patterns that are precursors to an event, these tools can establish patterns for normal operation and warn when the pipeline is not operating within those patterns. This can assist pipeline operators in identifying when the pipeline is operating abnormally, and help ensure continuous peak performance.

Rotating equipment

Rotating equipment, including electric motors, gas generators, pumps and compressors, are the most expensive elements of the pipeline and its operations. Confirming that this equipment is operating properly can help operators maximize utilization of the high-capital cost associated with these pieces of equipment and minimize energy usage.

Not surprisingly, rotating equipment has been the initial focus of predictive monitoring on the pipeline. There are two types of predictive monitoring for this equipment:

- Vendor-agnostic software, unaware of the mechanical design of a system but can identify patterns in the data leading up to an event.
- Vendor-specific models identify events based on knowledge of both a system's design and its historical operation across all of a vendor's customers.

Balance of plant

The savings associated with predictive monitoring on balance-of-plant equipment are primarily related to reducing work and increasing safety for maintenance technicians, as well as maintaining reliability and availability of the pipeline stations. While predictive monitoring for this equipment is not currently well understood, operators do see value in it and the level of predictive monitoring is rapidly expanding.

Pipeline Operation

The final, and currently unexplored, application of predictive monitoring is the pipeline itself. This includes monitoring macro values, such as flow, temperature, pressure and density, at each station to determine if the pipeline is operating at normal efficiency. Early warning that the pipeline operation is deviating from normal can signal the pipeline operator to investigate and perhaps correct reductions in productivity. Many of these degradations happen very slowly over long periods of time. Because of this, humans are poor at spotting changes. But mathematical models can identify them given sufficient historical data.



Condition-Based Maintenance

Predictive monitoring, whether through human analysis or mathematical models, allows pipeline operators to change from time-based maintenance to condition-based maintenance. The goal of condition-based maintenance is to only maintain equipment when it is required, rather than doing maintenance, calibrations, overhauls and other activities on a regular basis – even when they're not required.

A move to condition-based maintenance can result in a dramatic drop in routine work for field technicians and a corresponding increase in reliability, availability and safety, along with a reduction in costs. It also can move most maintenance practices from being reactive to proactive.

Conclusion

While implementing an optimization program for pipeline-equipment maintenance can be a sizeable undertaking for pipeline operators, such projects can provide a handsome return on investment as the changes become operational. Benefits include:

Safety

- Less time traveling to remote sites because of reduced maintenance activities, and enhanced abilities to remotely monitor and troubleshoot issues.
- Decreased interaction with operational pipeline equipment because of reduced maintenance activities.

Regulatory

- Increased auditable record keeping of pipeline operation and maintenance.
- Reduced control center alarms as more problems are identified and corrected before they generate an alarm.

Cost

- Reduced maintenance budgets.
 - Increased pipeline throughput due to higher availability.
 - More satisfied pipeline customers due to higher reliability.
 - Reduced recruitment, training and retention costs in a time of skilled worker shortages.
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For more information

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