Centrifuge Automation

To produce its class A fertilizer product, “Louisville Green”, the Morris Forman Water Quality Treatment Center needed to ensure dewatering consistency, and minimize polymer consumption.

For this project the Center selected the company who had installed the SCADA system for their recent dryer solids upgrade project, and who are also a supplier of Mass Flow Control Systems.

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The emulsion polymer used to condition solids makes up a significant portion of the Morris Forman Water Quality Treatment Center’s annual chemical budget. Operations and management (O&M) personnel want to improve polymer consumption to both cut costs and make solids processing operations more stable. So, the center added an automated control system to one of the centrifuges to optimize the polymer dose.

Centralized solids treatment

The Louisville (Ky.) Metropolitan Sewer District has about 30 water quality treatment centers, but only the 454,200-m³/d (120-mgd) Morris Forman Water Quality Treatment Center processes solids. The others send all their solids to Forman via force main or truck.

Altogether, the center manages about 64 dry Mg/d (70 dry ton/d) of solids (see Figure 1, p. 26). Primary solids are anaerobically digested, while waste activated sludge (WAS) is sent to dissolved-air flotation thickeners (DAFTs) and then to holding tanks. All solids from the other treatment centers enter Morris Forman via a solids receiving tank designed to send the slurry — which averages about 0.75% to 1.0% solids — directly to the DAFT process. Afterward, digested and thickened solids are blended and fed to high-solids centrifuges. The dewatered cake then is dried in rotary-drum dryers. The dewatering and drying systems operate on a 24/7 basis.

Morris Forman used to landfill its solids, but when the anaerobic digesters, centrifuges, and rotary-drum dryers were added between 2000 and 2002, the new goal was to create an exceptional quality biosolids product — Louisville Green — that the district would distribute. O&M staff quickly determined that dewatering consistency was the most important factor in effective operations. Inconsistently dewatered cake was a problem for the dryers, and staff dedicated much time and effort to managing polymer delivery, centrifuge torque, and differential to make dewatered cake as consistent as possible.

Also, polymer consumption was a significant portion of the chemical budget, and unfortunately, 2004 through 2007 was a volatile time in the polymer industry. The volatility was the result of

• price increases in the raw materials;
• fixed capacity in the United States for refining these materials;
• competition for these materials from other, more profitable industries;
• U.S. Department of Transportation regulations;
• natural gas prices; and
• polymer demands abroad.

So, polymer conservation became important. To minimize polymer consumption, experts recommended that treatment plants optimize their dewatering equipment via automation. Although market volatility has since eased somewhat, natural gas prices and raw material availability continue to make that recommendation viable. So, Morris Forman managers decided to pursue a dewatering automation system. They envisioned an automation system that would independently control and monitor the center’s five dewatering centrifuges, minimize dewatering costs, store and graph data, and connect to existing O&M and supervisory control and data acquisition (SCADA) systems.
More flexibility wanted

In preparation for the new automation system, O&M personnel modified the pumping system that transferred thickened WAS and digested solids to the dewatering wet well. Originally, there were no allowances for proportionally pumping the two streams; both pumps operated at the same rate, based on a wet-well level setpoint. O&M staff made three modifications so the pumping system would be more flexible.

They regeared each pump to change its capacity from 2.65 to 1.7 m³/min (700 to 450 gal/min), so the pump could operate at lower flow rates without overheating. This helped eliminate the need to reduce the minimum hertz of the pumps’ variable-feed drives, a contributor to overheating.

They reprogrammed the programmable logic controller (PLC) so they could apply a ratio to the pumps, biasing flows in favor of one solids stream or the other so staff could better manage storage tank and digester levels, as well as respond to upstream processes while minimizing the effect on dewatering and drying.

They installed another flowmeter in the line between the pumps and the wet well. Now, one meter measures total flow and the other measures digested solids flow (the PLC calculates WAS flow).

All of these modifications affect solids measurement. Accurate measurements of centrifuge feed solids, centrate concentrations, and polymer flow rate are important, because otherwise, the automation system’s decisions are flawed.
Automated control system

The automation system is designed to optimize the dewatering process. It monitors multiple variables, compares that data to operator-set parameters, and then adjusts dewatering components accordingly. The system can run for extended periods without operator intervention.

The automation system uses a PLC interfaced with the center’s existing SCADA system and PLCs. Operators can access the system via the SCADA system.

The system acquires real-time data via

- infrared suspended-solids meters, which measure total suspended solids concentrations in each centrifuge’s feed solids and centrate;
- deaeration vessels (one per centrifuge), which collect centrate samples;
- polymer flowmeters (one per centrifuge); and
- the existing solids flow reading.

The data the system uses include percent dry solids in centrate, percent dry solids in feed solids, feed solids inflow, polymer flow, centrifuge torque, differential speed, dollars per kilowatt hours, dollars per pound of active polymer, main drive amperage, and back drive amperage.

The automation system detects gross changes in centrate quality or clarity. Rather than checking for absolute increases (comparing the difference between current centrate data and a fixed level), it compares current centrate data to a dynamic setpoint, which adapts to both centrate quality and the potential for equipment fouling.

The automation system is started up once the dewatering system stabilizes. The system then begins its “knee routine,” which functions as follows:

- If centrate quality is within identified limits, a baseline is identified.
- The automation system then gradually lowers the polymer dose until centrate quality degrades.
- Then, it increases the polymer dose by 1% and goes into a holding pattern for a preset length of time.
- Once the holding pattern expires, the knee routine begins again.

This routine is repeated continually (see Figure 2, above). However, all setpoint changes must remain within preset boundaries. If it exceeds one of these boundaries, the system notifies operators that their attention is required.

Dewatering quirks discovered

The project team implemented the system in two phases. In Phase 1, the team installed the equipment for one centrifuge, programmed it, tested it, and analyzed test results (see Figure 3, p. 28). Center staff then reviewed the results and decided whether to proceed to Phase 2 (expanding the automation system to the remaining four centrifuges).

Readiness testing. Phase 1 had two testing segments: an operational readiness test and a performance test. During readiness testing, the project team verified that all instrumentation, communications between the PLC and SCADA system, as well as signal information, performed as designed. The most important issues were the accuracy and precision of the solids sensors, the flowmeter, and the cake calculations.

The team discovered that the pumping system modifications had more effect on cake calculations than on feed solids measurements. Future testing should allow for a cake-density factor based on the ratio of the two solids streams. At press time, the project team planned to evaluate the cake correlation and possibly modify the automation system accordingly.

The team also discovered that centrate sensor fouling hampered automation system operations. Gradual fouling of the sensor face obscured the quartz lens, causing the sensor to falsely indicate an increase in centrate solids concentration, which resulted in unnecessary polymer additions. The project team added a chemical cleaning system that kept the sensor lens clean so the centrate solids reading was more accurate. Subsequent sensor readings were accurate throughout remaining testing.

Performance testing. The project team began performance testing once the readiness test results were acceptable. Initially, the team planned to operate the centrifuge for up 180 days while the automation system managed polymer delivery and then compare test results to historical data to determine whether the automation system reduced dewatering costs. However, dewatering process changes made the historical data obsolete. Polymer consumption varies based on season and on the ratio of
solids being dewatered. So, rather than using historical data, the project team compared test results to the performance of one of the other four centrifuges and to the automated centrifuge with the system out of service.

Also, the volume of polymer added to individual centrifuges was not monitored by flowmeters. Instead, polymer doses were calculated based on pump speed. Because pump wear was unknown, it was impossible to determine actual polymer flows. To account for this unknown during performance testing, the project team used two efficiencies: 100% and 95%.

Another challenge during testing was regulating centrate via the deaeration vessel because of scaling in the sample line. Regulating flow is critical, because if flow is too high, deaeration will be incomplete, and if flow is too low, more fouling will occur in the sample line, and solids will collect in the vessel.

Also, operators’ tendencies to use polymer flow to make dewatered cake drier or wetter had to be corrected. So, the project team conducted training to ensure that operators knew that polymer was used to manage centrate quality and that torque was the primary factor in cake dryness.

In addition, operators also were not allowing the dewatering system to stabilize before starting the automation system, so it was optimizing against an erroneous baseline. As a result, the automation system tended to optimize at a higher centrate solids concentration than acceptable.

Center staff wanted the automation system to operate within certain boundaries of acceptable centrate solids and capture, so the project team set new limits and alarms on centrate solids concentration to limit alarms and further refine the polymer dose. Further limits may be included for more refinement (a limit on percent capture of centrate balanced against centrate quality).

As the project team worked through these challenges, it became apparent that the automation system was an excellent tool for managing polymer.

### Significant improvements

Team members compared testing data to performance data for the other centrifuges. They also evaluated differences in the test centrifuge’s performance with and without the automation system, because the lack of actual polymer measurement may have skewed the other comparisons.

Results showed that the automation system lowered the polymer dosing rate by 11.7%, saving about $40,600 in about 7 months (at the polymer price during testing; see Table 1, below). This savings was the result of only one centrifuge operating with the automation system only 71% of the time. Actual dose rates varied substantially, which could be due to the varying ratio of thickened WAS to digested solids. The reduction also takes into account potential pump wear, which would have reduced actual polymer flow (compared to calculated flow).

Centrate quality and percent capture were harder to quantify, because the automation system provides real-time data, while the centrate samples collected for analysis were composites. However, results indicated the following:

- The automated centrifuge produced cleaner centrate than the other centrifuges, meaning fewer solids returned to the liquid treatment train, so recycled solids costs dropped (see Table 2, p. 29). Also, the smaller standard deviation indicates more consistent operations, which resulted in better overall performance and more savings.

- The automated centrifuge produced a slightly drier dewatered cake than the other centrifuges, thereby reducing drying costs, because less water must be evaporated. Variations in the feed solids ratio will affect cake quality, because the two have characteristic dewatering properties; however, even if there was a 50% error in the cake calculation, the center could save $305/d for each percent increase in cake dryness.

- Power costs were slightly higher when the centrifuge was automated. The team attributed this to a slightly higher torque with

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**Table 1. Polymer dosing with and without the automation system**

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</thead>
<tbody>
<tr>
<td>Polymer dose rate (lb/ton dry solids), automation system off</td>
<td>83.6</td>
<td>75.9</td>
<td>71.5</td>
<td>91.3</td>
<td>70.5</td>
<td>87.7</td>
<td>75.7</td>
<td>75.3</td>
</tr>
<tr>
<td>Polymer dose rate (lb/ton dry solids), automation system on</td>
<td>71.4</td>
<td>73.7</td>
<td>71.1</td>
<td>58.8</td>
<td>64.7</td>
<td>73.4</td>
<td>60.6</td>
<td>66.5</td>
</tr>
<tr>
<td>Improvement</td>
<td>14.6%</td>
<td>2.97%</td>
<td>0.6%</td>
<td>35.6%</td>
<td>8.3%</td>
<td>16.3%</td>
<td>20.0%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>
the lower polymer use to maintain the desired cake.

During testing, the automation system was not shut down for any automation system-related reason, including maintenance.

Besides reducing the polymer dose rate, lowering recycle rates, and producing a slightly drier cake, the change gave O&M staff a better understanding of centrifuges. For example, they now understood that centrifuge torque—not polymer—is the primary factor affecting percent dry solids. O&M staff soon began to make the required torque adjustments, which helped reduce polymer consumption.

O&M staff also took a more holistic approach to dewatering as they better understood how the ratio of digested solids to thickened WAS affected both upstream and downstream processes.

**Important dewatering details**

Cake consistency is key to stable drying operations, and the automation system stabilized cake quality. Consistency is realized in fewer dryer adjustments, more consistency in dried product, and fewer cake-related maintenance requirements.

There is an algorithm for the ratio of digested solids to thickened WAS. The project team plans to add this ratio to the calculation of percent dry solids in cake. As the ratio varies, so will the cake factor, which should provide even more consistency in the cake's percent dry solids.

The key to good centrate measurement is a representative sample free of entrained air, which can introduce an error in the solids reading. Engineers should evaluate centrifuges individually when determining sample line location. They also should investigate deaeration vessel size, flow, and sensor location to maximize the deaeration rate. A flow switch in the sample line will detect low- or no-flow situations in the vessel.

Adding discrete solids sensors on the digested-solids and thickened-WAS feed lines can provide a true mass balance of solids to dewatering area. This information can be used by the automation system and in the center's mass balance calculations.

**Phase 2 under way**

Phase 1 clearly showed that the automation system makes dewatering operations more consistent. Proceeding with Phase 2 and implementing the recommendations will save money and further optimize dewatering.

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<table>
<thead>
<tr>
<th></th>
<th>Automation system off</th>
<th>Automation system on</th>
<th>Improvement</th>
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</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>973</td>
<td>884</td>
<td>9.1%</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>610</td>
<td>652</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>2470</td>
<td>1580</td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>355</td>
<td>219</td>
<td></td>
</tr>
<tr>
<td><strong>Capture</strong></td>
<td>93.2%</td>
<td>97.1%</td>
<td>3.9%</td>
</tr>
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</table>

A drier dewatered cake will reduce natural gas costs for the dryers. The project team should attempt to maximize the dewatered cake’s solids content without hindering drying operations. Again, the solids ratio will affect this effort. A new cake-factor routine, discrete sensors for each solids stream, and a better cake calculation will provide a more easily quantifiable cost savings attributable to cake dryness.

### Table 2. Total suspended solids in centrate with and without the automation system

*Note: The table shows the improvement in total suspended solids in centrate with the automation system on compared to when it is off.*

- **Average**:
  - Automation system off: 973
  - Automation system on: 884
  - Improvement: 9.1%

- **Minimum**:
  - Automation system off: 610
  - Automation system on: 652
  - Improvement: 3.9%

- **Maximum**:
  - Automation system off: 2470
  - Automation system on: 1580
  - Improvement: 58.6%

- **Standard deviation**:
  - Automation system off: 355
  - Automation system on: 219
  - Improvement: 39.6%

- **Capture**:
  - Automation system off: 93.2%
  - Automation system on: 97.1%
  - Improvement: 3.9%