Pumps and process energy optimization

Pumps represent a significant target for energy savings. The need to measure, monitor and manage consumption is viewed as an integral part of all process systems. Here, we demonstrate that a process energy optimization approach can allow energy consumption to be analysed and managed, giving potential efficiency gains of up to 30%.

Pumps are an ever-present application in the industrial world. Whether supporting industrial processes, HVAC systems or plumbing requirements, they represent a major consumer of energy for any industrial facility. The chart in Figure 1 provides some insights by industry of areas where energy savings can be realized, and it is clear that pumps dominate across the board. Pumps and pumping systems account for nearly 25% of all energy usage by industrial motors, making them a leading source of energy savings potential. In fact, they represent more than 50% of the savings potential (Figure 2), a statistic that many industries have yet to grasp.

Why is it that pumps and pumping systems represent such a sizeable potential? Several reasons can explain this opportunity, and provide some insight into solutions for significant energy savings. Some examples include:

- Applications where pump duty cycles have wide variance based on system demand. The variance could be a function of system usage demand, process fluctuations or other varying operating conditions.
- Oversizing – pumps are frequently oversized to allow for anticipated load demand or simply to provide an operational ‘safety factor.’
- Wear – pumps also wear over time, examples being impeller wear and bearing degradation, and this will progressively reduce the operating efficiency of the system.

Energy management schemes

The solutions to these challenges are a combination of both passive and active energy management approaches, as shown in Figure 3. Good examples of passive energy management include such solutions as the use of energy-efficient motors – a well-publicized and frequently preferred solution already implemented, and the use of ‘low consumption’ switching devices such as Schneider’s TeSys U self-protected motor starter (Figure 4), which can reduce device energy consumed by >90% compared to tradition starting methods.

A good example of active energy management is the use of variable frequency drives (VFDs), especially on centrifugal pumps; these allow the operator to match varying loads and represent tremendous energy savings potential.
savings potential in the process, due to what are called the affinity laws. Summed up, these laws state that:

- Flow is proportional to motor speed;
- Pressure is proportional to the motor speed squared; and
- Power is proportional to the motor speed cubed.

Another example of active energy management is process energy optimization (PEO). This approach provides for system profiling at optimum operating points, as well as constant monitoring and follow-up to provide feedback on system deviation that can indicate wear. PEO can yield efficiency gains of 15–30% in energy-intensive processes. It delivers value to end users with large pumping loads by providing:

1. Energy consumption data in the context of relevant production data;
2. Dynamic forecasting and modelling of energy usage tied to production plans and process settings;
3. The capture of energy events along with analytical tools to facilitate the elimination of the root causes of those events.

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Production data

Let us first consider energy in the context of production data. By combining real-time energy data with real-time process data, PEO allows operations personnel to visualize and understand the relationships between various aspects of energy and production. This integration of data takes place in the manufacturing execution system (MES) layer. The MES, or operations management,

layer is generally defined as functionality that fits between the operational data layer and the enterprise resource planning layer (Figure 5). Schneider Electric’s PEO solution combines the process-related MES analytical capabilities of its proprietary Ampla software with the energy modelling and forecasting capabilities of ION to form an active energy management platform.

Once the energy usage information is integrated properly with key process data, operations personnel can clearly and fully understand the important relationships between energy and process that drive consumption variability. An example of this would be a comparison of kWh/gallon of water pumped between different work crews, different raw material or feed types, as well as different process settings.

Once these relational comparisons are made, quality teams can determine where the largest variability exists and work to normalize performance around ‘best in class’ benchmarks.
Forecasting & modelling

Next, let’s examine the value derived from improved forecasting and modelling of energy. Using the regression analysis techniques and standards established in ASHRAE guideline 14 (available from: American Society of Heating, Refrigerating and Air-Conditioning Engineers; www.ashrae.org), PEO can closely model energy performance based upon a range of criteria, ranging from weather conditions, to production plans and process set-points. This tightly correlated model and resulting dynamic forecast allows the operations personnel to establish a framework that defines normal operation, and thereby identify energy consumption intervals that are ‘abnormal’ or that fail to meet minimum efficiency requirements. This forecasting methodology can be applied to the entire process, or to single, large pieces of equipment, such as a high kW pump. The example in Figure 6 shows a tightly correlated model based upon process feed rate combined with soak time – which is the time allowed for ingredients to mix before before pumping begins.

If applied to a single large piece of equipment, the dynamic energy forecast for that piece of equipment can be compared in real time to actual energy usage. If actual energy usage trends above the dynamic forecast, maintenance personnel can be alerted to potential nascent failure conditions before an unplanned process shutdown occurs.

Energy events

Finally, let us examine the concept of energy events. In short, an energy event is a period of energy consumption that is above the standards established as ‘normal’ or ‘acceptable’. Any
time an energy event occurs, PEO can capture all of the energy and process data relevant to the event. In order to identify energy events, one must first understand the typical behaviour of the end user’s industrial process in terms of energy consumption per unit of process output. This relationship is often referred to as energy intensity, or specific energy. Excess consumption is then understood to be defined as energy intensity that is above the normal range or band of consumption behaviour. Figure 7 shows an example of such an event, along with the data that is captured for analysis.

In this example, PEO captures the start time, stop time, duration, overconsumption, classification, cause, shift and crew associated with this event. Some examples of pump-related causes of energy events are as follows:

1. Suction cavitation due to low-pressure/high-vacuum conditions.
2. Discharge cavitation due to extremely high discharge pressure, normally occurring when a pump is running at less than 10% of its optimal efficiency point.
3. Concurrent operation of short-duration pump loads, such as backwash pumps, along with base-load commonly running pump loads.
4. Failure to monitor and optimize use of system-wide storage capabilities, thereby operating pumps more often than necessary for system mass balance.

As these records are captured and stored, a quality engineer can then perform failure mode and effects analysis (FMEA) to identify and correct the process-related causes of the energy events. As energy events become better understood and minimized or eliminated, the operations team can achieve active energy management savings of 15–30% whilst driving continuous improvement in energy efficiency.

In order to implement a PEO system, an industrial site must capture energy-metering information for the parts of the process that consume the most energy. This metering data must be fed real-time, along with process control set-points, into a database for real-time analytics and reporting. All PEO solutions are specific to the client’s needs and existing infrastructure. At the time of writing this article, more than two-dozen functioning PEO systems have been implemented.

Typical return on investment (ROI) figures for production energy optimization range from 20% in areas with high per-unit energy costs to 10% in areas with lower per-unit energy costs. Some examples along with key terms are shown in Table 1.

### Table 1. Typical PEO benefits.

<table>
<thead>
<tr>
<th>Company description</th>
<th>Process description</th>
<th>Solution summary</th>
<th>Estimated benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy construction equipment manufacturing</td>
<td>Discrete process, assembly teams</td>
<td>PEO for electric, gas, water</td>
<td>12% ROI</td>
</tr>
<tr>
<td>Battery manufacturing</td>
<td>High-speed automated assembly</td>
<td>Downtime reduction Energy savings</td>
<td>14% ROI</td>
</tr>
<tr>
<td>Paper mill</td>
<td>Continuous process with co-generation</td>
<td>PEO with cost allocation and billing</td>
<td>18-month payback</td>
</tr>
<tr>
<td>Silicon wafer manufacturing</td>
<td>Batch process</td>
<td>PEO with cost allocation and greenhouse gas (GHG)</td>
<td>15% ROI</td>
</tr>
<tr>
<td>Electrical product manufacturing</td>
<td>Discrete process, fabrication &amp; assembly</td>
<td>PEO</td>
<td>16% utility savings 28-month payback</td>
</tr>
<tr>
<td>Municipal water/wastewater</td>
<td>Continuous process, distributed architecture</td>
<td>PEO with power quality and GHG</td>
<td>22-month payback</td>
</tr>
</tbody>
</table>

Figure 7. Energy event monitoring.