Building and Operating Smarter Machines Using Automation Technologies and Analytics

Introduction and Objectives

What is a Smart Machine?

It is most likely the goal of every company to have Smarter Machines. But what is a "**Smart Machine**?" Ask 100 people that question and you will probably get 100 different answers. In my opinion the definition of a Smart Machine is pretty simple - a machine that can:

1. Provide information about how well it is performing.
2. Offer diagnostic information about its operational status.
3. Provide operators with instructions for maintenance and operations.

Why We Care About Smart Machines

This is a little different than "**Smart Manufacturing**" or "**Smart Processes**," where the machines can provide information centered on the output or production performance of the machines. (Concepts such as **OEE, or Overall Equipment Effectiveness,** have been around for decades and these capabilities continue to improve with solutions enhanced with new capabilities and solutions.)

However, a big part of creating Smarter Manufacturing processes is gaining insights into how the machines themselves are performing and what can be done to improve their productivity, availability, and efficiency within the manufacturing process. Smart Machines can provide this insight.

This document is a broad overview of how you can implement and create Smarter Machines. This is by no means an all-inclusive guide, as it should be expected that many new solutions for implementing Smart Machines have yet to be introduced and many solutions are available that space is too short to include in this document.

The Role of Data in Smart Machines

Smart Machines require information and information comes from data. The data is available in all of the devices located throughout the machine or from operating parameters that could possibly be measured but are often omitted from the original design of the machine.

Examples include:

- Current consumption from servo and inverter type drives.
- Electrical energy consumption and compressed air usage from the machine.
- Actuator response times.
- Encoder feedback from various motion positions within the machine, etc.

With data, we will usually find that data needs to be stored or logged. Building Smarter Machines can often require that historical information about the manner in which a machine operated in the past (for example, when it was initially commissioned) compared to how it is currently operating. This can often be the key to determine if a machine is performing in an optimal or Smart manner. In the building automation industry, the practice of continually monitoring machine operation is called **continuous commissioning**, and leads to significant improvement in the operational efficiency of a building and allowing building maintenance teams to work in a much more efficient manner.

Data can be recorded from almost any type of machine. The two most common locations to record data are **Microsoft SQL**, which is a database application (for many applications these are free, such as Microsoft SQL Express), or a class of software products called an Industrial Historian. An **Industrial Historian** is a software application designed specifically to log or record data for industrial and building applications. Many of the most prominent industrial software vendors will have an industrial historian product available to meet these needs. One area where industrial historians really shine is with the logging of what is termed ***timed-series data***. For example, a motor current or temperature that is logged every five minutes, with the associated time stamp of the data sample, is referred to as ***timed-series data***.

IOT and Smart Machines

If your company desires to utilize an IoT approach to creating Smarter Machines, then the data will be logged (collected) using a 3rd party IT provider (cloud service) such as Amazon Web Services, Microsoft Azure, or IBM. Some of the industrial software vendors mentioned above will have recommendations for using their products within a cloud-based environment and will often install their products in the cloud, so using a cloud service is essentially no different than an on-premise IT installation other than who provides the IT services.

Listed further on are a number of ideas and areas for certain aspects of a machine that can be monitored. Some of the areas that can be monitored are relatively high speed and will have fast changing data. Any data point needing to be monitored in less that ~1-second time increments will need to be initially collected in the machine's **Programmable Logic Controller (PLC)**. Most software-based data collection systems and/or **SCADA (Supervisory Control and Data Acquisition)** systems will not reliably capture data that is changing in less than 1-second increments. A PLC can capture and perform basic calculations in very short time increments and can easily capture time increments as fast as 1 milliseconds (1/1000 of a second).

You Have Data. What Does It Say?

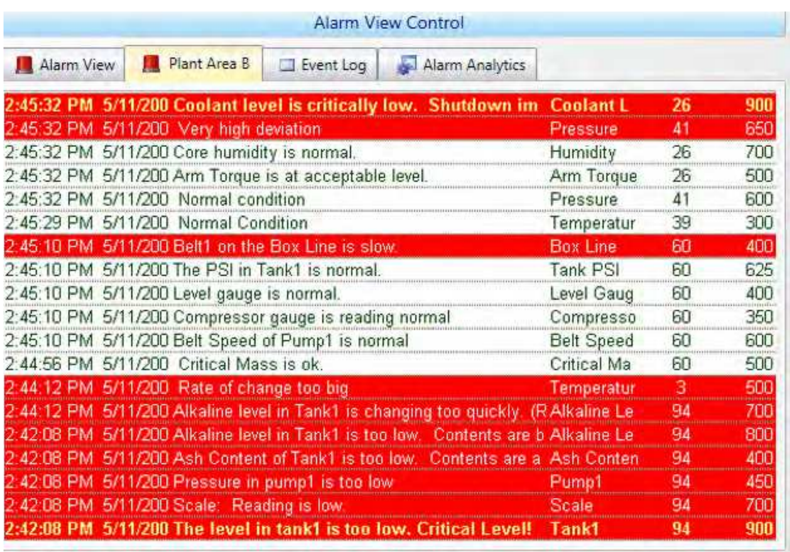
Once you begin to log various data, something has to be done with the data. The simplest next step is to present *time-series* data to key personnel in the form of trend graphs. **The trend graph will show changes in values over time and is an easily understood visual that allow key personnel to see changes in performance.** When this type of data is stored for extended periods of time, it is also very easy to begin to understand when a piece of equipment is no longer operating within expectations or when a piece of equipment has changed from its original design or installed performance.

The image below is representative of how trend graphs can display operation over time, and they can easily display how various equipment performs in comparison to each other.

Next, add additional context and/or decision making to the values of data being collected. This can be done using several well-understood methods:

- **Create something called an Alarm that will provide an indication when something has changed beyond a predetermined limit.** For example:
    - A temperature value might be too high or possibly too low.
    - A temperature value changing at a faster rate than should be expected in normal operation.
    - A piece of equipment that is starting too many times during the day.

  There is an entire field of study related to alarms and the proper use of alarms. One of the risks with using alarms is that the facility can create too many conditions and everything is always in alarm and the key personnel cannot make any sense out of what they should do. If Alarms are to be a strategy, invest the effort to understand best practices for alarming and implement those that make sense for your situation.

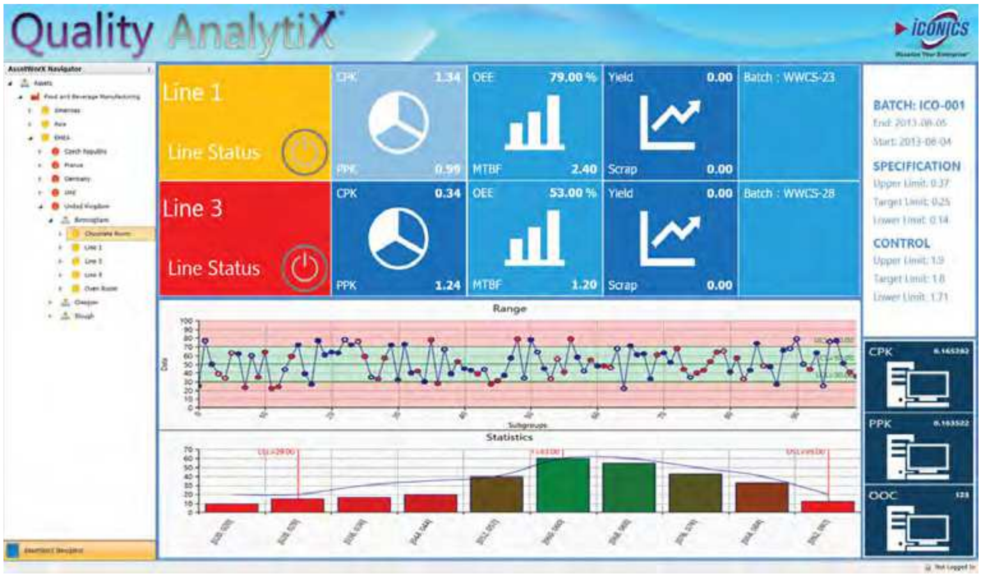

Alarm View Control

Alarm View | Plant Area B | Event Log | Alarm Analytics

2:45:32 PM	5/11/200	Coolant level is critically low. Shutdown im	Coolant L	26	900
2:45:32 PM	5/11/200	Very high deviation	Pressure	41	650
2:45:32 PM	5/11/200	Core humidity is normal.	Humidity	26	700
2:45:32 PM	5/11/200	Arm Torque is at acceptable level.	Arm Torque	26	500
2:45:32 PM	5/11/200	Normal condition	Pressure	41	600
2:45:29 PM	5/11/200	Normal Condition	Temperatur	39	300
2:45:10 PM	5/11/200	Belt1 on the Box Line is slow.	Box Line	60	400
2:45:10 PM	5/11/200	The PSI in Tank1 is normal.	Tank PSI	60	625
2:45:10 PM	5/11/200	Level gauge is normal.	Level Gaug	60	400
2:45:10 PM	5/11/200	Compressor gauge is reading normal	Compresso	60	350
2:45:10 PM	5/11/200	Belt Speed of Pump1 is normal	Belt Speed	60	600
2:44:56 PM	5/11/200	Critical Mass is ok.	Critical Ma	60	500
2:44:12 PM	5/11/200	Rate of change too big	Temperatur	3	500
2:44:12 PM	5/11/200	Alkaline level in Tank1 is changing too quickly. (R	Alkaline Le	94	700
2:42:08 PM	5/11/200	Alkaline level in Tank1 is too low. Contents are b	Alkaline Le	94	800
2:42:08 PM	5/11/200	Ash Content of Tank1 is too low. Contents are a	Ash Conten	94	400
2:42:08 PM	5/11/200	Pressure in pump1 is too low	Pump1	94	450
2:42:08 PM	5/11/200	Scale: Reading is low.	Scale	94	700
2:42:08 PM	5/11/200	The level in tank1 is too low. Critical Level!	Tank1	94	900

- **Consider *Statistical Process Control* (SPC)**. This is like viewing trend graphs on steroids and presents additional information and limits based on some standardized calculations and SPC rules. For some of your data, this may provide the insights that will help to better understand the performance of machines. Note: Statistical Process Control is usually applied for monitoring and understanding specific process related variables (temperature, flow, etc.) of the manufacturing process, but I have worked with some customers that have applied these same techniques to better understand how their equipment is performing.

  For reference, below is a sample screen capture from an SPC application:



- **Apply *Fault Detection & Diagnostics* (FDD).** This is a technique that has been used extensively in the building automation arena and utilizes mathematics and conditional logic (IF-THEN-ELSE) equations to determine how various parameters and equipment are performing compared to an expectation.

  This may be very simple, such as IF (a machine is ON) AND (it is after the close of business) THEN (turn machine OFF). This is simple equation that will help reduce energy usage in the facility. **When taken to the maximum limits, pieces of equipment could have dozens or hundreds of fault rules that essentially allows the equipment to be continuously monitored for any anomalies.**

  It also doesn't matter whether it is a simple piece of equipment or a very complicated piece of equipment (such as a wind turbine), each individual rule is intended to monitor one area or parameter on the machine and, as the rule set builds, the entire machine or system is continuously monitored. Fault rules can be implemented in supervisory systems (software) or can be implemented within the machine controller (PLC).

- **Utilize Machine Learning.** The concept of machine learning is a very broad and developing industry and is sometimes lumped in with the field of Artificial Intelligence. In simplistic terms, the collected data from machines are loaded into software that allows for advanced types of calculations and modeling of how the machine and/or process should be operating.

  Machine learning takes all of this data and can provide insights into how the machine is performing or will run in the future. For some very advanced types of machines (such as jet engines or wind turbines) the future predictions can significantly impact how the machine will be maintained or how the machine will perform. In the case of a jet engine, some very critical issues, like safety, might be a goal, while with a wind turbine, the need for information might be related to financial performance based on power output from the turbine.

Industry still has a lot to learn about the field of Machine Learning but, eventually, these tools and use cases will become more readily available and we may see all types of interesting results from advanced analytical solutions. Currently Machine Learning and Artificial Intelligence applications are all being deployed used cloud-based services. Due to the speed requirements in industrial automation, expect to see new controllers and ideas for implementing Machine Learning and Artificial Intelligence techniques in more traditional industrial control platforms.

Regardless of where the data is stored, a key and essential element of any Smarter Machine initiative is to consider who the consumers of the information will be and how will they get the information.

You Have Data. How Is It Presented?

Once data is collected and initial analytics (alarming, SPC, FDD, etc.) are performed, this information needs to be delivered to the personnel best able to act on the information. **The information also needs to be delivered in the most effective fashion for your facility.** In today's manufacturing environment, information might be delivered to computer screens, large format displays hanging on the factory floor, to tablets, to smart phones, to wearable devices (smart watches, hands-free tablets, headsets, etc.), or information might be delivered in the form of reports.

Do not underestimate the power of Microsoft Excel. Excel is an immensely powerful tool for processing, calculating, contextualizing, and presenting information. **However, I will make note that any use of Excel should be automated.** Reports should be automatically populated with data, reports should be run automatically, and should be distributed automatically (email, printed, stored on a server, etc.) Reports that take significant manual intervention to complete will ultimately lose value – automate the reporting functions!

The graphic image below is representative of the types of devices that information can be delivered to with today's industrial software solutions, and get ready for the use of wearable technology – lots of innovative and great solutions being deployed using wearables (smart watches, hands-free tablets, etc)

Ideas for Creating Smarter Machines

Utilize embedded web pages from smart components

Leverage the capability already existing in the components installed on the machine, especially with new machines. For example, if the machine is less than 5 years old, many of the major components (such as Ethernet switches, bar code scanners, drives, pneumatic manifolds and some smart sensors) will have an integrated web page as part of the product. These web pages almost always have some data and information about the performance of the device.

As a minimum, these web pages should be embedded within the machine operator interface so the information is visible. If this is not possible, then these web pages should be embedded within some type of a machine SCADA system implemented to provide overall insights into the machines operation.

Monitor and historize process sensor data

Monitor process sensors (flow, temperature, pressure, etc.) for change over a period of time.

It is very possible that process sensors can fail or the communications to the sensor (via analog I/O signal or network) can experience issues. To monitor this, the FDD software should monitor all process sensor values for change over a specific time period.

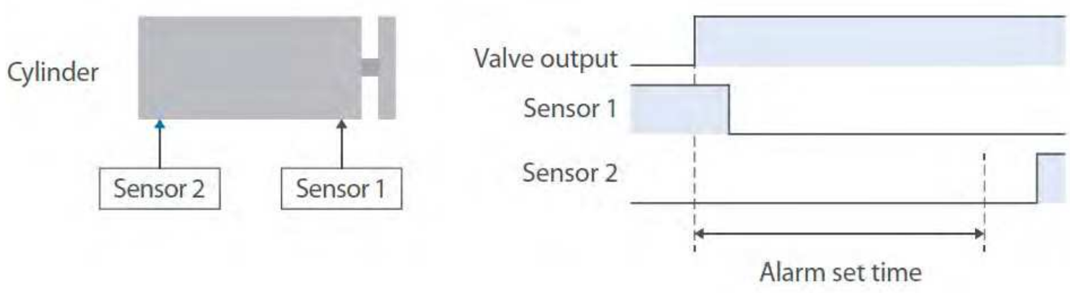
For example, a temperature sensor should expect to see at least 1% change in value during a 4-hour time period. Process sensors are used in almost every industry. The process industry obviously requires the measurement of pressures, flow temperatures, tank heights, etc. and even discrete manufacturing industries use process sensors to monitor energy usage (both electrical energy and compressed air), motor speeds and currents, etc.

Monitor pneumatic actuators for proper operation

Pneumatic actuators or cylinders are highly reliable and cost effective devices used in machines to create mechanical movement of a sub-system within the machine. Over time, however, pneumatic actuators can suffer from a variety of issues that will negatively impact the machine performance.

- Actuators can become worn with internal seals degrading allowing for less than optimal performance.
- Damage can occur with machine jams that can cause the actuator to become bent or deflected from its factory state.
- The compressed air energy source, either from the valve to actuator tubing, or at the value itself, can be degraded over time such that the actuator cannot operate at its most effective performance level.

• Operators can make adjustments to energy sources (compressed air) to fix a problem in one area of the machine and negatively impact another area or actuator.



The basic method for monitoring a pneumatic actuator is to measure the cycle time for the extension and retraction of the cylinder. **Monitoring this time can identify immediate performance issues and by tracking this value over time can reveal a slowly degrading performance.**

> Note: the time resolution for this type of monitoring action will most likely be needed to be measured in the machine controller (PLC). The time can then be collected and logged in the data collection system for long term evaluation and fault diagnostics.

When monitoring pneumatic actuators, don't forget to consider the energy source – the compressed air. At a minimum, monitor the machine compressed air pressure. Changes and fluctuations in air pressure can have detrimental effects on the machine performance. For even better monitoring, add air flow sensors to detect the volume of air being consumed by the machine. **If this changes over time, especially if it increases, the machine is increasing in the cost to operate and may indicate the initial phases of worn components within the pneumatic segment of the machine**. Solenoid valves and actuators may have seals that are beginning to wear and not seal properly, allowing air to leak. If these components degrade significantly the machine performance will decline.

Monitor electrical actuators & mechanical actuators in a similar fashion as pneumatic actuators

Electrical actuators provide similar functions as pneumatic actuators but will have a stepper motor or servo motor attached to provide the energy source vs. the compressed air used for pneumatic actuators. Electrical actuators also have the added portion of the product that is the mechanical portion. This may include gearboxes, internal drive belts, ball screws, etc. These mechanical components all have a rated lifespan based on the forces they are subjected to by the servo motors driving the actuators. These types of equipment will also have some type of longevity rating that could be expressed in total travel distance (for example, a 400mm actuator might have life expectancy of 20 million mm of total travel distance, or 50,000 strokes – extension and retraction actions).

This gets a little complicated because the life expectancy ratings are not always published and are always based on the full load rating of the component. When the component operates at less than rated load, the life expectancy can be expected to increase and, conversely, when the component operates at greater than expected load, the life expectancy will be reduced. These projected life expectancies can be dynamically calculated and monitored by tracking the torque output from the servo motor operating the actuator and then using the manufacturer's specifications to calculate the projected life expectancy of these components and subsystems.

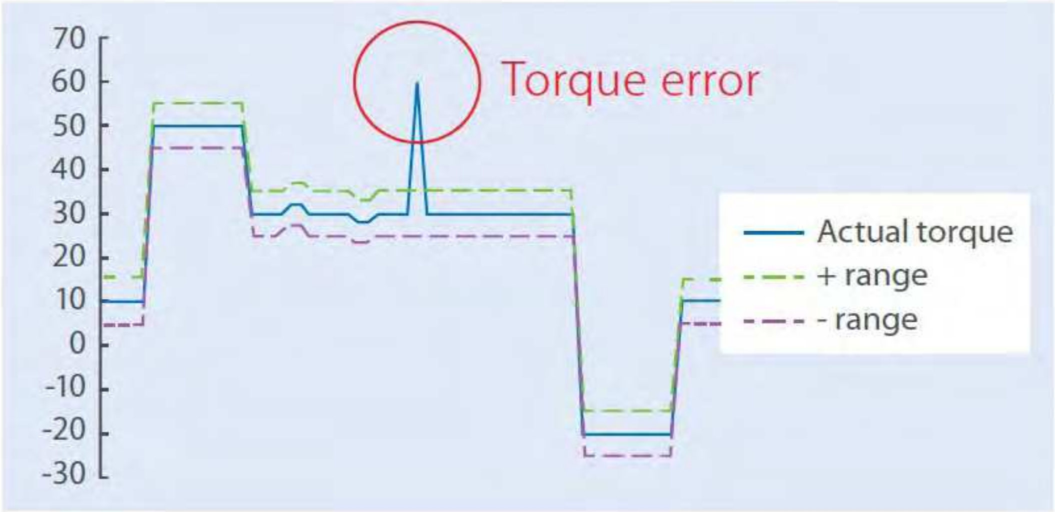
Why is this important?

Electrical and mechanical actuators can be expensive and, depending on the design, may have long delivery lead times. These types of actuators are seldom in stocked at your local supplier and so a failure will create an extended downtime situation. **Accurately knowing when you might need to replace the component will allow for improved maintenance planning.**

Monitor the torque output for servo motors

Servo motors are connected to some type of mechanical load. If a problem begins to appear with the mechanical load, it is often reflected in the need for the servo motor to increase the amount of torque applied to the load to meet the performance requirements of the machine. **Monitoring this torque output can help to identify when conditions surrounding the load being driven by the servo motor has deteriorated from the original design performance.**

If possible, log the torque output data for comparison to historical performance. Some analytical solutions will also allow for the saving of an "Ideal" torque output vs time and the actual performance will be analyzed vs this "ideal" performance. Any changes can then become immediately obvious.



Why is this important?

If as servo motor requires the delivery of more torque to complete the assigned move, then something in the system has changed. It is possible that this increase in torque will generate forces in the mechanical components (gearboxes, actuators, etc.) that **will significantly reduce the life of these mechanical components and lead to premature or unexpected failure and resulting downtime of the machine.**

You Can Similarly Monitor Robots

Many manufacturing companies utilize robots as part of their processes. **A robot can also be looked at as a six-axis motion control system. Each robot axis has a servo motor and usually some type of a gearbox.** The monitoring principles for robots are similar to monitoring servo motors and other types of mechanical systems. By monitoring key operation parameters (such as output torque, force, or temperature), a change in value can be an early warning indicator that something is going wrong. This allows the maintenance team to take appropriate actions and develop repair plans if deemed necessary.

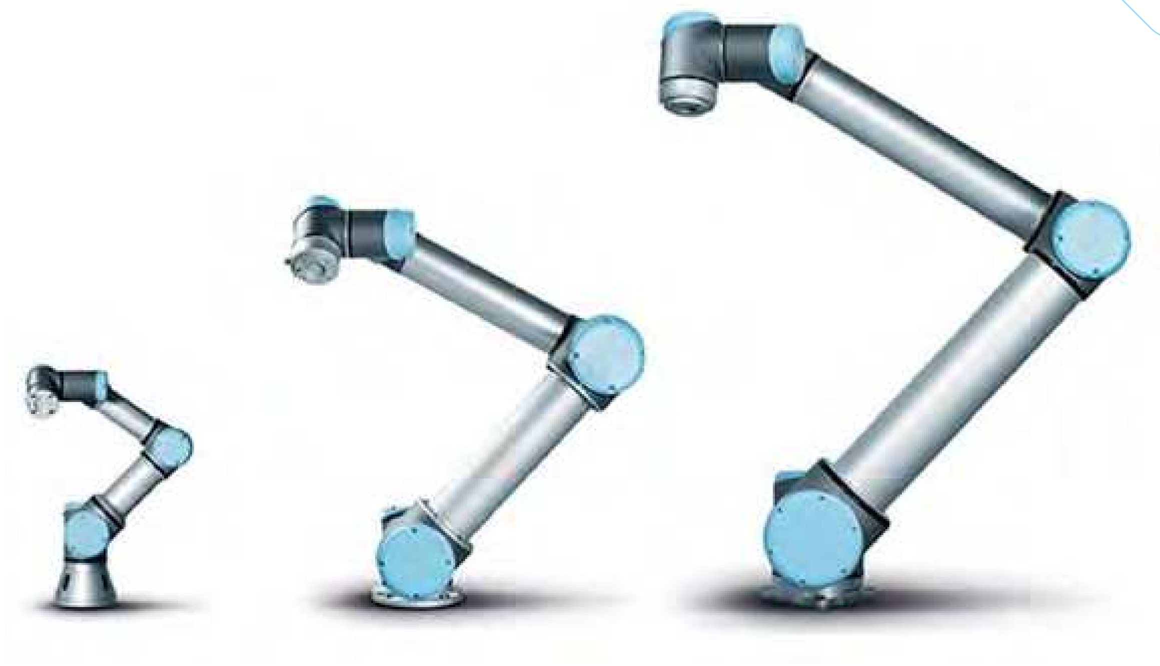
Cross Company represents several robot vendors and we are most successful with a newer robot technology called a collaborative robot. This manufacturer currently offers three different size robots, sized by reach and payload, but has designed commonality amongst the sizes such that there are three joint sizes. They have also provided a standardized set of parameters about the operation of each joint axis as well as some data points about the operation of the robot.

Joint operation parameters include:

- Joint velocity
- Joint current
- Joint temperature

Individually these parameters provide some insight into how each joint is operating, but if the data collection system is monitoring and providing an alarm on joint temperature (for example), it would be beneficial to also have the joint current consumption as well to see if the joint is consuming more current than normal, which could indicate an electrical or increase load demand. If the current has not changed from normal operation and the temperature is still elevated, it could be an indicator of some type of mechanical fault that is causing the generation of extra heat. Either way, the unexpected increase in temperature from normal is indicative of a change away from normal operating conditions.

Other standardized parameters can also be used to monitor how well the robot is performing. There is a data point available to indicate if the robot is POWERED ON and the above mentioned Joint Velocity data points. These can be combined into a calculation to determine how much time the robot is operating. If the robot is powered on and the joints are not moving, then the robot is not working. Data points are also available to indicate when the robot is in EMERGENCY STOP mode and if some type of SAFETY SIGNAL is ON. These variables can be combined into a set of calculations (called analytics) to help get a better understanding of how effectively the robot is performing and how much of the total available operation time is being used for real work, or interrupted by unexpected stop conditions.



Why is this important?

Robots are expensive pieces of equipment, are difficult and time consuming to repair, and often perform critical functions that cannot be easily completed by humans if the robot is not available. **The better informed the company is about how well its robots are performing, the better the company can do to manage its investment in this automation technology.**

Monitor all electro-mechanical electrical components for total operations count

Most machines have a variety of solenoids, relays, motor contactors, and other switching devices that all have a limit to the number of mechanical and electrical cycles for which they are rated. The industry calls these electro-mechanical devices because they all operate with the same principle – an electrical solenoid that creates a linear movement for the energy switching function.

For example, a relay has a series of contacts that are moved together using an electrical solenoid. When energy is applied to the electrical solenoid, the relay contacts engage and a signal or power connection is created. **Once an electro-mechanical component exceeds it rated number of operations, the likelihood of a potential mechanical failure increases.** When a component will fail mechanically is not an exact science, so it is best to track all of the operations of the devices on the machine and provide information to the maintenance team. It may make sense to take proactive action to replace components that have exceeded their expected design life spans.

Why is this important?

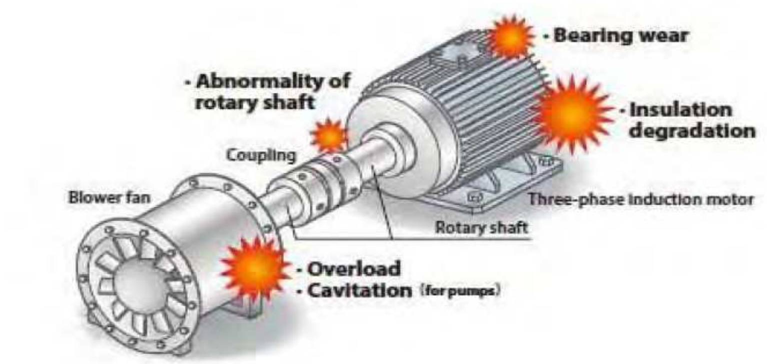
The various electro-mechanical electrical components in the machine all have a limited number of operations cycles before they can be expected to fail. By design, these devices have both an electrical and mechanical life cycle limit. For example, a relay will have a projected number of electrical switching cycles as well as a total mechanical life cycle. Monitoring the operations of these devices will provide insights to the maintenance team about when components are getting closer to their project end of life allowing for planned maintenance and attempting to avoid downtime situations caused by component failure.

Monitor 3-phase induction motors

The 3-phase motor is the most common type of electrical motor in use in factories and buildings. These are also the single largest consumer of electrical energy in most facilities. These types of devices are everywhere – they run pumps, compressors, fans, conveyors, blowers, and almost every type of equipment. These motors can also be monitored. Talk with your local motor expert for methods for monitoring motors, but consider doing some type of monitoring. Techniques that can be applied include:

- **Measure each of the phase currents being consumed by the motor.** I am aware of one company that compares the level of each current being measured to the other phases, and triggers a fault when the phase-to-phase difference exceeds one standard deviation. This company views this difference as a pre-indicator of an impending failure and take appropriate maintenance actions.
- **Apply conditioning monitoring sensors to measure vibration, temperature, and current.** One company has advised of being able to predict a motor failure up to one week in advance from when they began to see an upward movement in these measured parameters.

There are also some recently introduced motor condition monitoring sensors that can detect electrical anomalies that can indicate an upcoming problem with a motor.



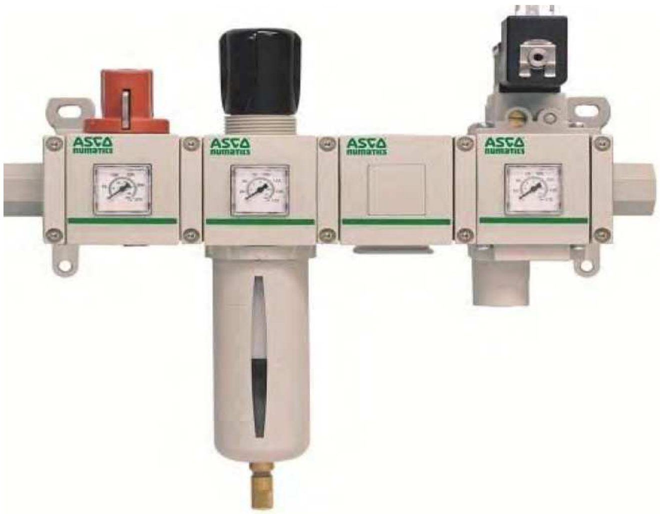
Monitor the energy consumption for the machine, both electrical and compressed air

Electricity and compressed air are the two most common forms of energy used by automated manufacturing machines. **Monitoring the use of these energy sources helps build a Smarter Machine because changes in the use of these energy sources can be an early indicator that the machine is not operating at peak levels of performance.**

Monitoring electricity is fairly cost effective. Machine-mounted electrical meters cost from about $250 to $500 plus the cost of the current sensors (CT's) at about $50 to $100 per phase. One of the nice benefits of using energy meters at each machine is the amount of information that can be gathered - phase-to-phase current usage, all three phase voltages, power factor, power, etc.

Measuring compressed air consumption is getting easier due to some recently introduced sensors. Typically, the only parameter available for monitoring compressed air at a machine is pressure. Most machines that use compressed air will have an FRL unit for filtering the compressed air for contaminants and for removing water that may be mixed in with the compressed air. Some of the FRL units will also have a pressure regulation function and a small gauge to indicate what the air pressure is at the FRL unit. Adding a sensor that monitors the pressure and ***air flow*** by a host system allows an analyst to better understand the compressed air usage. The changes in the usage patterns can be identified and may indicate detrimental performance issues with the machine.

Picture below is of a FRL unit for a typical machine:



Utilize the protocol of IT (SNMP)

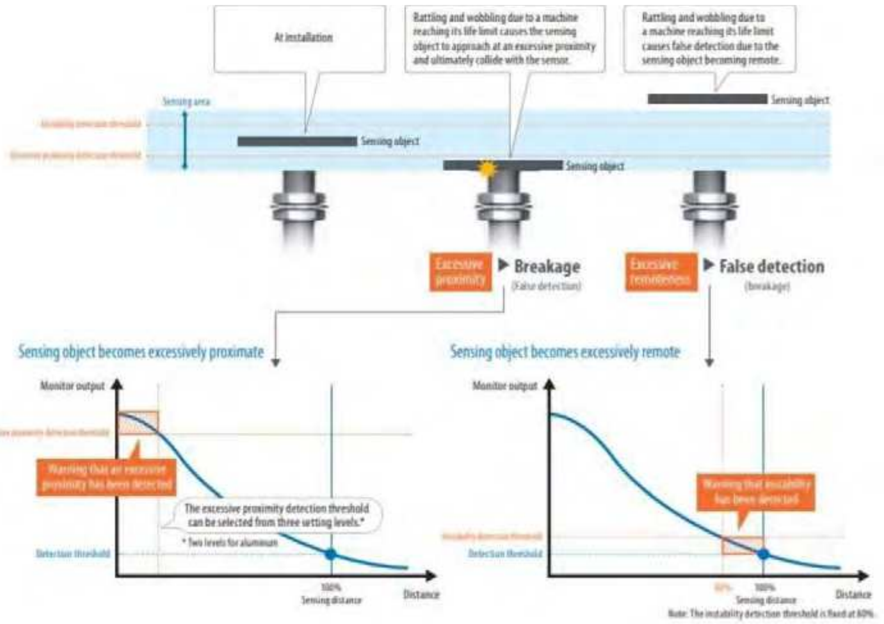
Leverage the protocol of IT – **SNMP (Simple Network Messaging Protocol)** to monitor the performance of networked devices (switches, routers, computers, etc.). As manufacturing and production systems have become increasingly complex, the amount of networking equipment used on the manufacturing line has increased dramatically. **Most of this equipment has a communications protocol included with the product that can be leveraged to understand the performance of this networked equipment.**

Something as simple as monitoring the heat of a computer CPU can indicate the operational health of the computer and **it is increasingly important since the primary factor in many electrical devices long- term health is the negative impact caused by heat.** By knowing that a piece of equipment is being thermally stressed (by heat), better decisions can be made to manage the equipment for the long term health of the production system.

Implement sensors that have diagnostic functions

This may not be feasible for existing machines, but should be considered for new machines. Technologies such as I/O Link allow for sensor status communications to each sensor in addition to the standard signal ON/OFF or variable value. Proximity sensors are used extensively in almost all industries and are used to detect the presence of a metal object. Proximity sensors have a relatively small sensing range, usually in terms of millimeters.

Smart Proximity sensors can detect differences in the position of the object being sensed. (See image below). These differences in position can be an indication of an impending issue with the machine, typically, that something has moved and is no longer operating along the same path as originally designed.

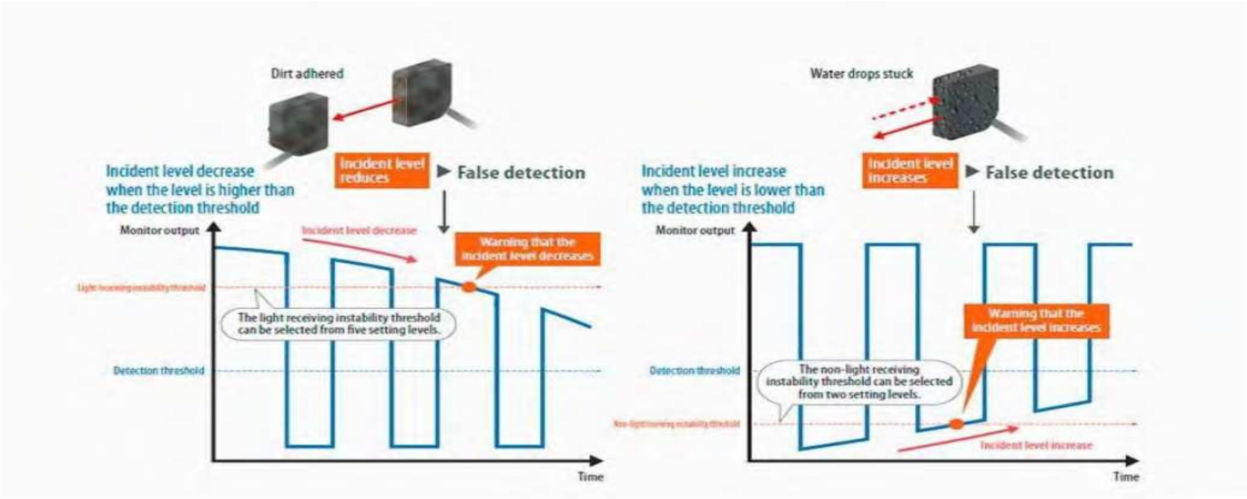


Photoelectric (optical) sensors can also be deployed to provide feedback about the operational status. Some photoelectric sensors monitor the light intensity being received after every operation of the sensor (operation is defined as the light return being interrupted to the receiver). A decreasing amount of light energy can indicate several potential problems including:

- Dirt or fluid build-up on the emitter or receiver.
- Misalignment of the emitter and receiver.
- Partially blocked emitter or receiver (trash build-up).
- Or, in the event of older sensors, a degradation of the output light energy from the emitter.

These conditions can typically be resolved very quickly by the operator or maintenance technician. The value of this information being the prevention of potential downtime events on the machine. **The graphic below is an example of how monitoring the incident light level within optical sensors can be used to identify potential operating issues.**

Reduction in faulty output due to unstable output



Monitor circuit protective devices for operation

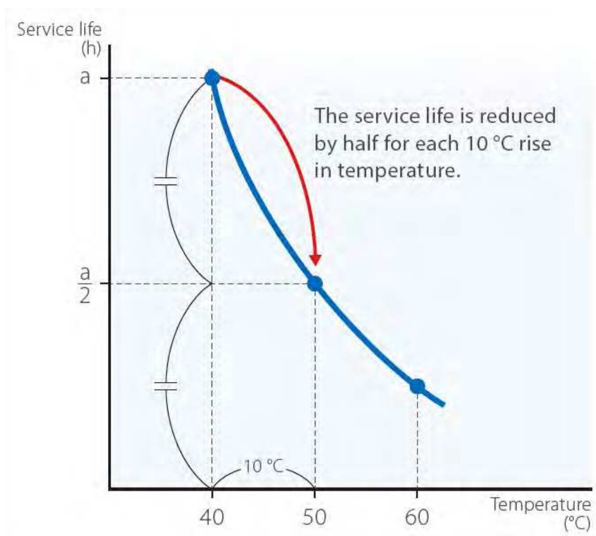
All machines have electrical protective devices that are required based on governmental electrical codes. These devices are intended to provide safety to personnel around the machine and to minimize the risk of catastrophic issues like a fire caused by an electrical malfunction. Smaller machines may only have a single protective device on the main electrical circuit for the machine electrical system, while larger machines may also have branch circuit protective devices in addition to the main electrical devices. These electrical protective devices may be fuses and/or circuit breakers. Normally these devices protect against longer duration over current abnormalities that can cause overheating problems and also protect against very short duration abnormalities that can cause short circuit problems.

Monitor power supplies

Almost every machine in the United States has a 24VDC power supply. These devices become a standard item in the early 1990's as electronic components, such as sensors, became popular. To allow for reduction in size of these components, low levels of DC power became the norm. Power supplies have a limited life due to the use of internal capacitors. These power supplies are also subject to handling various levels of current based on the devices connected to the power supply. Current flow creates heat and heat is one of the primary reasons for premature electrical failures.

The picture below is for a 24VDC power supply, designed for electrical control panels for machines that includes an Ethernet interface. Via this communications interface, up to 14 parameters can be monitored including output voltage and current, projected years until replacement, total run time, overheating alarm, and also can provide the unit part number allowing maintenance to have accurate information related to potential replacement if needed.

Relationship between service life of an electrolytic capacitor and temperature



How To Get Started

The majority of this document has been about ideas for monitoring various sub-components within a machine, but the **question you may have is what steps to take to implement an IoT approach to create Smarter Machines.** Below is a series of steps to take for moving forward.

- **Assemble the key personnel on your team** and determine if creating a Smarter Machine approach for your facility makes sense. Determine who will lead the effort.
- **Take an inventory of your machines** and take note of what available communications interface may be available on the current machine controller. Most machines utilize a controller called a Programmable Logic controller or a CNC (Computer Numerical Control) controller.
- **Engage with the maintenance team** to gather information about repairs and work orders for each of the identified machines. This information can be the basis for beginning to build smarter machines so the previous failures can be predicted and either eliminated or corrected before a downtime event occurs.
- **If your machines are commercially built by a machine builder, contact that machine builder** to see what ideas and/or assistance they may be able to offer on your journey to Smarter Machines. If your machines are custom to your facility, then it will dependent on your team to identify areas that can be monitored to create a Smarter Machine approach.
- **Schedule meetings with potential suppliers** of industrial software products to provide the data logging, analytical functions, and information delivery to key users within your company. The industrial software market is very broad and has many potential suppliers, some of which might have some very good ideas for how they can be of assistance.
- **Get started.** Understand that creating Smarter Machines is a process and the sooner you get started, the quicker the potential benefits.

As mentioned earlier, the building automation industry has adopted some of the techniques outlined in the document and the results are truly impressive. Many large building owners, such as universities, are completely revolutionizing how they maintain the mechanical equipment in the building and are seeing dramatically lower operating costs as a result of applying some the approaches discussed in this white paper.