Life Is On | Schneider Electric

Why creating intelligent machines may not be as difficult as you think: a practical blueprint

by Erik L. Barnes

Executive summary

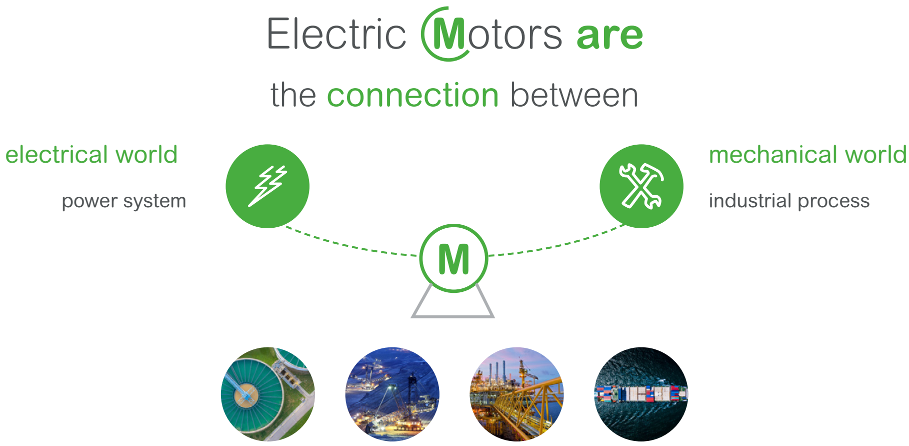
With changing market dynamics that impact workforce availability, production costs, and product lead times, there is a growing interest in increasing the productivity and intelligence of machinery and equipment. Much has been written about industrial internet of things (IIoT), but machine asset managers and machine designers still struggle with how to practically implement and use the many types of data that IIoT can deliver. This paper discusses the application of intelligent motor starters in terms of how the data relates to motor/load performance, and the methods to apply this data to practical applications, resulting in greater productivity and labor utilization.

Introduction

Electric motors: the heart of efficient machines and equipment

Electric motors are integral to industrial environments, infrastructure, buildings, and more, running pumps, conveyors, compressors, augers, blowers, etc. to keep machines and equipment whirring. As part of the power conversion chain from the electrical source to the mechanical system, motors turn electrical power to rotational mechanical power.

Electric motor controls present a strategic opportunity for original equipment manufacturers (OEMs) looking to improve machine efficiency, optimize performance, reduce energy consumption, minimize unplanned downtime, realize faster time to market, and possibly yield new business models — thanks to digitization and the IIoT.



Factoring in the motor load when building machines and equipment can deliver these benefits. The motor and its connected load converts electrical energy to mechanical energy that the mechanical operation realizes as a practical benefit to the operation. It accomplishes a specific function — whether a conveyor moving mining material or consumer products, a compressor keeping refrigeration units running smoothly, a pump moving water, or a fan drying freshly harvested grain for silo storage.

Electric motors respond differently in different conditions and situations. Understanding how motors perform in these conditions opens new opportunities to better manage equipment health, energy consumption, productive output, and overall operational efficiency. These performance indicators are the key to recognizing when adverse conditions are present or when action is necessary. This knowledge is the foundation of realizing a higher level of machine intelligence. Given the key role electric motors play in many different types of processes, there is a tremendous opportunity to enable a higher level of intelligence that will impact many individuals and businesses.

Chapter one

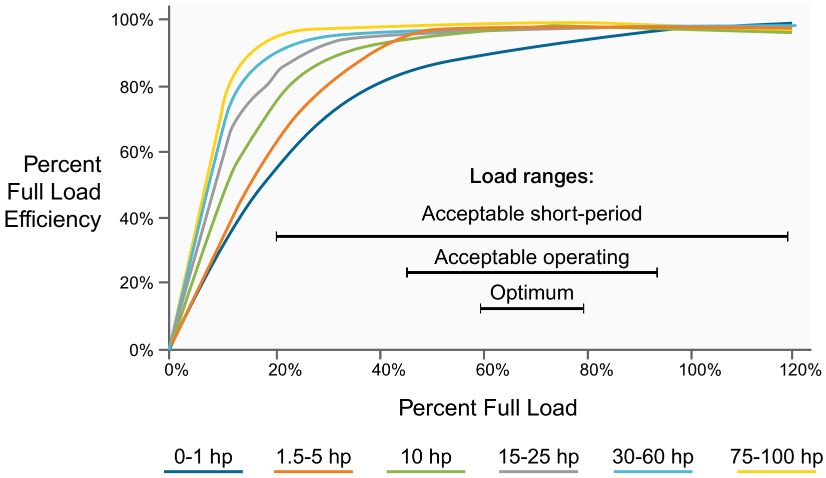
Opportunities for improvement

Customers and markets are dynamic, with ever-changing challenges, priorities, and needs. This gives rise to new opportunities for improvement, ideas, and solutions. Enhancing machine intelligence is an excellent vehicle to realize needed improvements.

Understanding motor usage

To optimize machine performance and power efficiency, a machine must be able to alert on factors that may require more power to accomplish the same amount of work, such as required maintenance or poor power supply attributes like power factor, voltage, etc. Visibility is key for ensuring that machines can achieve that balancing act of running smoothly and efficiently at the same time.

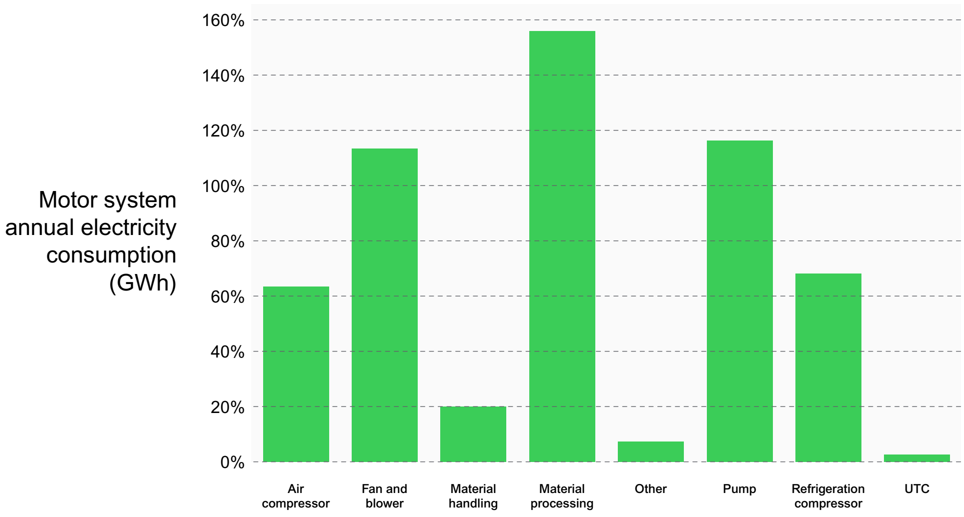
Since operators tend to run electric motors at their nameplate speeds instead of the optimal speed aligned to the load, embedding machines with simple intelligence to alert on power factors can improve the opportunity for energy savings. As the U.S. Department of Energy points out, "Most electric motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of rated load […] with efficiency decreasing dramatically below about 50% load." [1]



U.S. Department of Energy:
Motor Part-Load Efficiency (as a Function of % Full-Load Efficiency)

This common misalignment affects the machine's energy efficiency. Visibility of the motor/load performance, the energy consumed, required maintenance needs, and any power supply factors that may influence these three metrics will help end users with their sustainability goals. Without visibility to where energy is being used efficiently (or not), they simply cannot effectively manage their energy consumption.

[1] U.S. Department of Energy. Determining Electric Motor Load and Efficiency. April 2014. Available at https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf



Industrial motor system annual electricity consumption by driven equipment. UTC indicates that the equipment driven by the motor could not be identified.[2]

Unlocking efficiency opportunities

Indeed, electric motors have come a long way since their invention in the 19th century. With the rise of digitization and the IIoT, motor control solutions have evolved as well. Once limited in function, motor controls are now smarter because of embedded data-driven intelligence that has transformed motor control and protection from reactive to proactive, limited in scope and function to dynamically adaptable based on data insights, and restricted by the motor location to remote-enabled capabilities.

This new level of industrial evolution has resulted in the ability to safely plan downtime with minimal impact to production. By integrating intelligent load management at the machine design-and-build phases, OEMs can help mitigate some effects and shortcomings of traditional motor control methods: unplanned downtime, higher repair costs, reduced productivity, negative impact on profit, carbon impact, and end-user customer dissatisfaction. Visibility of real-time motor efficiency metrics unlocks these opportunities.

Embedded intelligence does not have to be complex. It can be simple intelligence that enables easy alerting while still making great strides toward better machines and long-term optimal performance.

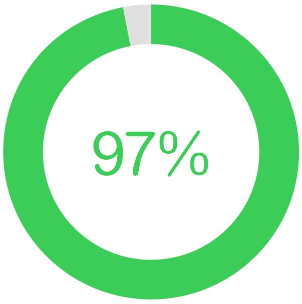
[2] Energy Technologies Area Lawrence Berkeley National Laboratory U.S. Industrial and Commercial Motor System Market Assessment Report, January 2021. LBNL-2001382. Available at https://www.nema.org/docs/default-source/motor-and-generator-guides-and-resources-library/u.s._industrial_and_commerical_motor_system_market_assessment_report_vol_1_4cbc82a3-a08a-462d-a774-e637c9998c8a.pdf?sfvrsn=853d7fb9_3

Additional practical benefits for embedded machine intelligence

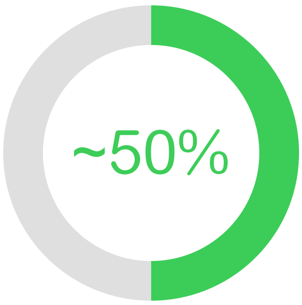
Baked-in motor intelligence has practical implications that will solve other common challenges for most end users:

1. Closing the skills gap

Manufacturers are grappling with limited availability of maintenance and operator personnel. Nearly one-fourth of the U.S. manufacturing workforce is older than 55,[3] thereby leading to what the Manufacturing Institute calls "'brain drain' (i.e., the loss of institutional and technical knowledge)." [4]



of manufacturing firms
are worried about "brain drain"[5]



are "very concerned"
about the aging workforce[6]

This impact of a widespread skills gap is significant for the U.S. manufacturing sector, which is facing an estimated 2.1 million job openings left unfilled by 2030, costing the U.S. GDP approximately $1 trillion.[7] To make matters worse, the "Great Resignation" is hitting manufacturing the hardest, according to The Washington Post: "Manufacturing has weathered the biggest surge in workers quitting — a nearly 60% jump compared with pre-pandemic." [8]

Embedding load intelligence in the motor control system helps to fill some of the glaring skills gaps widened by a retiring workforce and the "Great Resignation." By giving operators an intuitive "check engine" light, an unexpected problem can be fixed easily before significant impact.

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[3] The Manufacturing Institute. The Aging of the Manufacturing Workforce. July 2019. Available at https://www.themanufacturinginstitute.org/research/the-aging-of-the-manufacturing-workforce/

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] National Association of Manufacturers. "2.1 Million Manufacturing Jobs Could Go Unfilled by 2030," May 4, 2021. Available at https://www.nam.org/2-1-million-manufacturing-jobs-could-go-unfilled-by-2030-13743/?stream=workforce

[8] Long, Heather. The Washington Post, "Why Manufacturing Has Seen the Biggest Spike in Workers Quitting," January 9, 2022. Available at https://www.washingtonpost.com/opinions/2022/01/09/why-manufacturing-has-seen-biggest-spike-workers-quitting/

2. Reducing unplanned downtime

Equipment wear, poor power conditions, operating outside the performance boundaries, and occasional mishaps can lead to a machine unexpectedly stopping. Smart motor control helps stave off unplanned downtime by providing visibility to key performance and operational parameters. For large, multinational industrial plants, the financial impact of unplanned downtime can be enormous: $532,000 per hour, totaling about $172 million per plant annually (based on lost revenue, financial penalties, idle staff time, and restarting lines).[9] Consider a grocery store scenario when a refrigeration unit goes out: "The total cost of an unplanned refrigeration outage can easily be five times greater than the direct maintenance costs." [10]

27 hours

average total of monthly unplanned downtime per plant — more than a full day's lost production[11]

Although there are many contributing factors to industrial downtime, motor load woes can be better managed. Data can be used to set early warnings for motor load problems, capture diagnostics information, and inform predictive maintenance models.

Consider, too, situations where equipment is difficult to service, such as a line of remote pumping lift stations — a line that runs for many miles. Should a pump need maintenance, it can be difficult to locate and/or take time to reach, resulting in higher labor costs to keep equipment running. Simple intelligence provides remote visibility of load conditions that can affect the performance and efficiency of the pumping equipment.

3. Improving plant safety

Intelligent load management can raise the bar on plant safety. Having greater visibility to set the terms of maintenance engagement, as opposed to reacting to the immediate situation handed to maintenance/operators, creates a safer environment for maintenance workers.

Several factors can escalate the risks to safety when dealing with down equipment/ machinery. Pressure to quickly resolve and get equipment running again can distract workers who are trying to diagnose and correct down equipment, leading to mistakes and potential injury.

Consider, too, that some motors are in confined spaces, or may be elevated, adding complexity to troubleshooting and repairing equipment. Some applications involve the presence of chemicals or hazardous materials, and some machinery involves processes that have the capacity to injure workers, such as cutting, presses, or moving apparatuses. Managing maintenance in a controlled, planned fashion where the downtime is scheduled is a much more favorable situation for personnel safety.

[9] Senseye, "The True Cost of Downtime" report. Available at https://www.senseye.io/downtime-report-download

[10] Anderson, Turner, "The Hidden Costs of Refrigeration Outages," April 28, 2021. Available at https://www.axiomcloud.ai/blog/refrigeration-outages

[11] Ibid.

Chapter two

From basic to intelligent motor control

The current state of motor control and protection relies on mechanically responsive equipment that is incapable of providing insights should a problem occur. In many cases, a motor or load issue goes unnoticed, eventually leading to an unplanned machine stoppage followed by troubleshooting and corrective action.

Traditional motor control protects motors from burning up during a prolonged excess motor current condition, but this is a reaction only to a single-symptom, high-running current. There are myriad reasons for high-running current, of which traditional motor controls provide neither a warning nor a diagnosis of the specific cause. In other words, this approach provides no visibility into what's going on and why the problem occurred in the first place.

If there is too much weight for a conveyor motor to handle, for example, the motor current will rise above the motor Full Load Amp (FLA) rating. Should that overloading condition persist, the starter will turn off the motor. With traditional motor control and protection, the system doesn't tell the operator that it senses a problem beforehand or, just as important, why it trips. If an end user is a large distributor, the operator would have to scramble to figure out why a conveyor stopped.

Even more tedious, they likely can see which conveyor had the overload, but they may be dealing with shutting down the other portions of the conveyor before its contents spill onto the floor. If this is an agriculture conveyor, for example, produce that hits the floor cannot be put back on the conveyor, resulting in lost goods. By contrast, an intelligent motor control provides insights for data-driven response before significant impact on the distribution or production line.

Overloading is not the only issue that motor loads face that lead to downtime. In some cases, underloading can lead to equipment damage, such as is the case with pumps that have insufficient liquid supply, resulting in cavitation and eventual damage.

In addition, some types of equipment are prone to jamming or binding, such as auger systems or conveyors. In these cases, the motor will see a very high rise in motor current, for which most overload protection devices eventually will trip the motor circuit. Traditional motor protection devices, however, do not provide the reason for the stoppage, nor a warning.

A simple, intelligence-based motor control system provides this historically missing visibility to non-normal operating events or other conditions. Detecting issues prior to a stoppage gives the machine designer the opportunity to program the equipment to either take a specific remedy action or alert for needed maintenance using a pilot light indicator, touch-screen alert, or even a signal sent to a control room or a mobile phone. This knowledge can help operators run the equipment for efficiency, help facility managers better manage energy consumption, and help technicians more proactively manage the machine maintenance.

Which issues can smart motor starters detect?

The motor load is the device — whether a conveyor, pump, auger, or fan — connected to the motor that's doing all the work. Many scenarios can create problems with both immediate (a machine stops working) and long-term consequences (irreparable wear and tear; wasted energy consumption).

Let's consider a few of these scenarios:

A machine won't turn.

A jam in the machine will create a big spike in current. A traditional motor control system will recognize the large rise in current and trip the motor start circuit. Embedded intelligent motor control, however, can see the spike, signal an alarm, and allow the operator to respond immediately to the jam before the motor burns out.

In this case, the equipment designer has the option to choose how to address a jam condition. For example, a jammed auger could be reversed momentarily in an attempt to clear the jam. A traditional overload relay will trip the circuit, so the motor is not a risk or burnout. The operator or maintenance technician also has to run down the list of possible causes, whereas the smart motor controller can advise of the specific issue or potentially clear the jam without involving personnel.

A pump is running dry.

This scenario will create a noticeable current drop on the pump; this change is likely to go unnoticed because traditional motor control would allow the pump to continue running, leading to cavitation and eventual damage to the pump. Intelligent motor control can sense the drop, stop the pump, and alert the operator/maintenance to address the reason for the upstream drop in flow.

A filter in an HVAC or blower equipment is dirty.

The current will drop on the motor because airflow is suppressed through the filter due to excess dirt/dust. The equipment can be configured to alert maintenance when it's time to replace the filter. Traditional motor control will not respond to low current. As a result, filters may become so dirty that cooling/heating efforts require a longer runtime, and thus more energy to regulate temperature. The other solution is replacement of filters on a routine basis regardless of whether it is really necessary, which could be an added expense.

A refrigerator unit has a low charge.

An alarm from a smart control system can alert maintenance to service the unit before it shuts down and the end user loses product.

A conveyor is moving material that's too heavy.

This scenario would cause an overload trip on one or more motors in a line of conveyors. With control intelligence, you can alert upstream to slow or stop the material feed to allow the conveyor time to clear and cool the motor, thus preventing a stoppage with potential lost/damaged materials.

Fans are not operating in a drying process for food production.

With an enclosed fan dryer system in a food processing plant, an operator can't see if a fan stops running, thereby affecting product quality. With motor control intelligence, the operator gets an alarm to maintenance the fan as soon as it fails to run.

In short, a motor control system with simple intelligence allows operators to correlate motor performance with load performance easily.

Using power measurements to drive sustainability objectives

Being able to monitor energy consumption specifically where the energy is used is crucial for meeting sustainability objectives. Meters can be placed on the power distribution gear to monitor consumption, but this can be cost prohibitive to place traditional meters at each load. Users can observe increases in energy consumption for the facility or a particular section but cannot easily identify the contributing machines or loads affecting the increase.

By contrast, intelligent motor controls that monitor energy and power parameters allow stakeholders to see which loads are abnormally high. With smart motor load management, however, an asset manager can see which of the various loads in equipment are running inefficiently (possibly indicating maintenance is needed) or are operating at unnecessary times and, in turn, make energy-saving adjustments.

Indeed, electric motors for industrial use offer huge potential for reducing energy consumption. As International Energy Agency's (IEA) Executive Director Fatih Birol has said, "At IEA, we call energy efficiency 'the first fuel' — which shows the significance of energy efficiency."[12] Additionally, "energy efficiency improvement will drive more than 40% of the reduction of energy-related greenhouse gas emissions over the next 20 years,"[13] according to the IEA.

[12] Whiting, Kate, "Energy Efficiency is World's 'First Fuel' and the Main Route to Net Zero Says IEA Chief," January 25, 2022. Available at https://www.weforum.org/agenda/2022/01/iea-energy-efficiency-worlds-first-fuel-net-zero/

[13] Ibid.

Chapter three

A simple, practical approach to leveraging motor control intelligence.

Enabling machine intelligence is an emerging field that piques the curiosity and interest of those thinking about the future, but one can easily become overwhelmed when considering the amount of data that IIoT can offer and how that data should be interpreted. Starting the journey toward a more intelligent machine doesn't have to be a complex affair. Let's take a look at what a simple approach to intelligent motor control means on a practical level:

Precise vs. indicative

Most engineers are naturally inclined to achieve precise, accurate, and repeatable diagnosis when considering a means to detect a particular set of issues. This precision, however, can often seem like a paralyzing proposition considering the amount of issues, variables, and analysis.

A warning system doesn't have to be detailed to the exact issue, however, in order to be helpful. Instead of a series of precise alarms, one could consider a general alarm based on an indicative approach. An indicative approach is akin to a check engine light on a vehicle. This indicator doesn't advise the specific problem to the user, but it informs them that a mechanic is needed to check, diagnose, and repair the issue before leading to possible damage to the vehicle. Adjusting the mindset to indicative motor control versus precise control can be a game-changer for OEMs, allowing for effective load management in real time without complicated programmable logic controller (PLC) programming.

For example, there are myriad things that can go wrong with a compressor. A precise approach to determining the root of a problem would take multiple sensors, wiring, additional I/O to the PLC, and additional logic, not to mention a lot of trial and error. An indicative approach, however, is much simpler and beneficial for signaling that a problem exists or, even better, alerting on a brewing issue. Remember, traditional motor controls provide no warning of an issue, so even a simple “call maintenance” alarm at the first sign of an issue allows maintenance time to investigate.

Normal vs. abnormal operation

Motors are sized to perform a certain amount of work (horsepower, or HP); however, the actual loading may not be known at the time of design/motor selection. To avoid under-sizing the motor, they are typically sized based on the upper end of the expected work-demand range. The fully loaded capacity of a motor is indicated by its Full Load Current (FLC) or FLA rating. Once a motor is loaded with the actual work to be done, the running current is often less than the motor FLA rating.

Understanding this concept is important to recognizing an abnormal operation. A motor operating at 95% of its FLA rating, when it normally runs at 75% of the its FLA rating, may require maintenance that otherwise would go unnoticed with traditional overload protection.

Some load types have a fairly constant loading, such as may be the case with a pump that moves the same amount of water the same distance. Other loads may be variable, as could be seen with the moving of different materials on a conveyor. Whether constant or variable, there is typically a normal operating current range for a motor load. Under normal operating conditions, the motor current should stay within a certain range.

But what happens when motor current strays outside its normal range? There can be one or several causes that result in a motor operating outside its normal operating current range, depending on the type of load. Undercurrent, a condition where the motor current is under the normal operating range, could mean the equipment isn't being loaded up (and could be turned off to save energy), or it could indicate other issues such as pump cavitation, a broken conveyor belt, a compressor system that needs maintenance, or a dirty filter that needs to be replaced.

Overcurrent is when the motor current is higher than the normal operating range. This could mean loading is unusually high, a compressor system needs maintenance, or there is possibly too much demand downstream. A steep rise in current (called a jam) is another indicator of an issue such as debris blockage or a mechanical bind.

A motor control system with simple intelligence raises the bar by gleaning and delivering real-time insights to make machines smarter and more reliable. Compared to a traditional motor control and protection, an intelligent system can leverage data insights to better switch, protect, and manage motors and other electrical loads.

	Issue	Motor current characteristic	Traditional motor control		Smart motor control	
			Response	Possible outcome	Response	Possible outcome
Conveyor	Blockage	Jam	Overload trip - no warning	Unplanned downtime	Detectable - Issue alarm	Auto-reverse to clear jam
	Excess weight	Overcurrent	Overload trip - no warning	Unplanned downtime	Detectable - Issue alarm	Pause infeed to clear load
	Belt breakage	Undercurrent	No response	Material backup/loss	Detectable - Issue alarm	Alert maintenance to fix
Pump	Blockage	Jam	Overload trip - no warning	Unplanned downtime	Detectable - Issue alarm	Auto-reverse to clear jam
	Debris interference	Overcurrent	Overload trip - no warning	Unplanned downtime	Detectable - Issue alarm	Alert maintenance to clear
	Cavitation	Undercurrent	No response	Pump damage	Detectable - Issue alarm	Stop, alert operator - no flow
Compressor	Excess leakage	Overcurrent	Overload trip - no warning	Excess energy consumption	Detectable - Issue alarm	Schedule service to address leaks
	Low charge	Undercurrent	No response - excess energy consumption	Compressor damage	Detectable - Issue alarm	Schedule service to correct charge

Consider, for instance, what typically happens when a single conveyor belt at a mining plant is overloaded. Overloaded motors can overheat and lose efficiency, prompting the motor to shut down and causing the cascading effect of material piling up down the line. Now the operator has a bigger problem on their hands than the original overload scenario. A dustup on the production line, downtime, and an operational disaster that could have been avoided. How? By smarter motor control that allows the operator to alert upstream.

Instead of automatically shutting down a single overloaded conveyor and causing disruption down the line, an intelligent load management system can detect a brewing problem based on set parameters (e.g., acceptable current level for the load). In this way, the equipment can be programmed to respond to an alert proactively before operations are disrupted.

Plant operators need better visibility of these motor-to-load scenarios in real time (and, in some cases, remotely) to know when the current is operating outside the normal range to best reduce cost and energy use while improving performance and safety. Traditional motor control protects motors in the event of an overload. That's a starting point, but one that doesn't move the needle on managing performance and energy use in a meaningful way.

Cloud analysis vs. indicator alarm

Advanced motor control products that provide motor current and voltage data have been around for some time, but equipment designers have not adopted this technology en masse. This is not because there isn't a need for smarter motor control. In most cases, the lack of adoption is the outcome resulting from the challenge in interpreting these data points. Suppose a system reads the motor current is running at 13.6 amps. Is that acceptable, or does action need to be taken? There's also the challenge of setting up a way for the equipment to gather, analyze, and take appropriate action.

One approach to data interpretation is to collect various data points in the cloud where performance trends can be defined after an observation time period. Data operating outside the normal trend can be flagged. Looking purely at trends can help spot anomalies, but interpretation of an anomaly and the decision if action is necessary may not be clear without application context. This approach to trend data is certainly achievable with today's solutions, but it can also involve increased data-processing capability, additional commissioning, and potential cybersecurity complexities.

Another approach uses a PLC. True, a PLC program can be written to read and respond to abnormal motor current, but it's not easy to set or adjust, and processing the amount of data points can be very taxing on the processor. Simple intelligent motor control has solved this conundrum with the feature of alarms. Instead of repetitively providing data to the PLC or trending software for analysis, alarms can be set in the intelligent motor control to send a signal when a motor parameter is beyond the alarm boundary setpoint. Alarms are the key to making data more practical to realize new equipment capability. They open doors to better information, increased performance, and even more revenue. Alarms are customizable, allowing the programmer or installer to easily set parameters that trigger a warning. For example, an undercurrent alarm can be configured in the motor starter settings to be 60% of the motor FLA.

Let's suppose an installer notices this alarm is too sensitive during commissioning. Changing the sensitivity isn't an issue with intelligent motor control. The undercurrent alarm setting can adjust easily and be retested to confirm the correct sensitivity.

Intelligent alarms, instead of traditional motor controls, are capable of informing operators or maintenance teams when action is needed. This early insight can help end users tremendously by giving them the information to help run efficiently, increase output, and keep equipment healthy. It also allows them to manage maintenance proactively instead of reacting to unplanned downtime.

In addition, alarms pave the way for OEMs to increase revenue through post-sale monitoring services and replacement parts. Knowledgeable maintenance staff and operators are retiring faster than they can be replaced. This technology gives OEMs an opportunity to realize revenue by providing needed services to keep their equipment running. Alarms inform the OEM directly that service is needed or they can inform operators that service is needed, prompting a call to the OEM.

With intelligent motor management solutions in place, maintenance personnel have more warning and information at their fingertips when they troubleshoot. Abnormal situations can be addressed before they become critical and cause a production stop through alarming that is based on preset behavioral parameters.

Chapter four

Steps to devise an intelligent motor control solution

Enabling intelligence can be a complex affair depending on the desired diagnostic accuracy and precision. However, an early indicator, even if not as specific, is still very beneficial toward proactively managing equipment, and much simpler to implement. A basic, practical intelligence scheme is much easier to devise using a methodical approach.

Follow these steps to devise a motor control solution with simple intelligence:

1. Identify/prioritize most important issue/need
2. Identify measurement indicator
3. Establish measurement means
4. Leverage existing alarm or establish data interpretation method
5. Set and validate the alarm trigger point
6. Determine actions following alarm
    a. Equipment action
    b. Communication action
    c. Personnel action
7. Repeat for other important issues/needs

1. Identify/prioritize most important issue/need

Motor and load performance can be affected by many factors, but some are more likely and more impactful than others. Start by focusing on the problem of highest priority for the specific load.

For example, an auger used in a grain dryer is subject to jamming if a foreign material enters the bin. This is a real concern as the grain in the dryer can be exposed too long to heat, compromising the quality.

2. Identify the measurement indicator

The next step is determining the motor attributes that are affected when the issue occurs. There can be several indicators for a particular issue. A particular indicator can also be present for multiple issues.

The key here is to choose enough attributes to reasonably indicate that the issue is occurring. From the grain dryer example, a sharp rise in current can be an indicator that the auger is not able to freely operate, implying a blockage. Identify the measurement indicator — in this case, a setpoint for jam detection.

3. Establish the measurement means

A machine builder could add a current transformer (CT), but that requires manually adding the CT to the motor circuit and wiring the CT to an analog input on the PLC. This method also requires the PLC to interpret the jam condition. Instead of this complex approach, a machine builder can use an advanced starter with an embedded CT that can detect a jam condition as the measurement device for detecting current.

4. Leverage an existing alarm or establish a data interpretation method

With a CT approach, logic must be written so the PLC can interpret the measurement to detect the jam condition. The logic will need to recognize the difference between a jam verses other factors that can increase the motor current, such as an overload. This can be a complex affair.

By contrast, an intelligent motor control system with a configurable motor-attribute data alarm provides a much simpler way: configuring a jam alarm set to trigger when current rises 500% for longer than 1 second. This alarm signal will occur with enough time before an overload trip occurs, allowing for proactive measures to be taken. This method does not burden the PLC device with excess data and logic execution — it's looking only for whether a jam alarm has triggered or not.

5. Set and validate the alarm trigger point

As stated earlier, the motor running current is often lower than the motor FLA, depending on the actual loading of the work to be done. Thus, the normal running current versus the abnormal running current may not be able to be fully determined until the unit is installed and in operation. An initial alarm setpoint level can be established for the relevant protections such as undercurrent or overcurrent based on expected levels in the initial setup/configuration phase.

For some types of equipment where the load is known or consistent, this initial setpoint level can be based on experience in observing motor current in certain conditions. Often, equipment can be set up in a lab or testing area where the affected conditions can be created or simulated, and the motor current behavior can be observed. One such example includes compressors involved in packaged cooling equipment where the system is built and defined with the equipment.

Other types of equipment may be more dependent on the connected loading, and the initial setpoint can be more difficult to define. In these cases, the setpoint can be fine-tuned in the field during the commissioning phase or once in operation. Smart motor control that can be easily adjusted with an accessible interface, either on the physical equipment or by remote connection, is key to executing these adjustments.

6. Determine the actions following alarm

Once an indicator alarm is triggered, what should be done? The answer depends on several factors. The severity of impact is one consideration. If nothing is done, what happens to the operation/output, the equipment, and personnel?

In the example of the grain dryer, the risk is poor product quality should the auger jam. Likely there is no impact to the equipment, as the motor circuit would eventually trip due to an overload. Should the equipment be exposed to harm in a different scenario, then more urgent actions may be necessary.

What actions are normally taken in the absence of an alarm should the event occur? In the case of the grain dryer, personnel would likely have to clear the jam following a trip event as mentioned before. This presents a potential injury risk to the operator. Are there actions that can be taken when a jam alarm is triggered that could eliminate or reduce the need for a person to intervene? In this case, it could be possible to clear the jam automatically by reversing the direction of the auger momentarily. It may require limiting the number of attempts, stop the dryers, and call for maintenance should the jam not successfully clear.

One other consideration is communication. Who needs to know about the alarm? Who needs to know if subsequent actions were taken? How time-sensitive is this information? In the example of the grain dryer where the jam is detected and attempted to be cleared, then maybe no one needs to be alerted immediately. Instead, the equipment designer may construct a monthly log of such events that can be viewed locally or emailed to a service provider. In the event that the jam cannot be cleared, the local operator is likely the best one to inform. This could be done using a simple “JAM DETECTED” pilot light. Or if the operator may not always be present, then an audible stack light may make the most sense.

The actions to perform when a specific alarm is detected will differ based on the type of equipment and personnel involvement. These actions can be viewed from the following three perspectives:

Equipment action: The action can range from shutting down the equipment to something as simple as activating a pilot light or making a simple log entry. The key factor for the equipment involves the risk of damage to the equipment, to the process or product, or to personnel.

Personnel action: The action of personnel depends on the type of equipment, impact, and urgency. In some situations, operators may need to be aware of a condition so they can more effectively operate the equipment or process. In cases where maintenance is needed, maintenance technicians should be informed. Some types of personnel such as facility managers do not need to take immediate action but should be informed for some types of alarms.

Communication action: This is the way to inform the proper personnel as needed. To alert the operator at the equipment, a pilot light or message on the door may suffice. In a remote pumping station, though, the alert may need to go to an operator who is 20 miles away, thereby requiring a mobile phone text or a cloud-based communication. In short, determine the communication actions to take and who needs to be involved. Also important is the type of information that needs to be communicated. Those providing a maintenance function would benefit in some cases by receiving more detail on the indicator alarm and relevant motor attribute data. For industrial engineers or facility managers that are not involved in the day-to-day operations, but are responsible for managing equipment assets, a monthly log may be beneficial.

7. Repeat these steps for other important issues/needs

Here are some other industrial scenarios and how to use smart motor load management to leverage simple intelligence:

Auger:

In the application for moving concrete mix into a dispenser, augers push down the mix. The operator cannot see situations when these augers get jammed. One way to solve this lack of visibility is by placing a sensor at the output to detect whether the mix is flowing into the dispenser. Mounting the sensor in the right position can be tedious and impractical (e.g., running the sensor cord back to the PLC).

Luckily, there is a simpler way. A smart motor starter that looks at the motor current can determine if there is a jam condition based on setpoints (e.g., six times the FLA). Instead of just stopping the auger, the smart control can have the system reverse for a second to try to get the mix to follow the way and then push forward again. The smart starter also can tell when the auger is not pushing enough load, indicating that it is empty. The machine builder can set an undercurrent alarm to automatically stop when the auger is done to avoid spinning.

Pump:

Pumps with consistent loading (e.g., lift station moving the same amount of water the same distance) will often have a consistent running current. Smart motor controls can be deployed to monitor for abnormal current levels, such as a drop in current (indicating a possible cavitation condition). A prompt shutdown may be needed in this case to prevent damage to the pump. Pumps may eventually develop a leak due to aged seals or loose joints. An overcurrent alarm can help inform technicians that servicing may be required. Debris blockage or interference can also hamper some types of pumps, where jam detection or overcurrent detection can be deployed. In these cases, it may be possible to initiate a reverse flow temporarily to clear the debris. If successful, the operation can keep running without the need to involve personnel.

Blower/fan:

In a commercial building or lab, the blower system constantly filters the air, moving it around to keep the temperature even and regulated. Clean rooms also use blowers and filters to maintain air quality. Certain industrial equipment in dirty environments may use blower/filter systems to keep motors cool and clean. As these filters collect dirt and dust, the traditional method is to inspect or replace it on a regular schedule.

A smart motor control can set an undercurrent alarm, which is an indicator that the filter is too dirty because less air moves through it. Then the maintenance step matches the replacement timing more accurately while optimizing energy consumption to regulate air temperature.

Compressor:

Compressors are used in many systems that provide compressed air, cooling, refrigeration, and other outputs. There are several issues that can affect compressor performance, prompting some sort of maintenance needed. It's challenging to precisely diagnose without installing various sensors. The good thing about compressors, however, is that if something is abnormal in the system, motor current is likely to move outside a normal operating range.

A smart control system can alarm when the steady band of operation exceeds or drops below the current, indicating a problem (much like that "check engine" light on a car). Current changes can indicate one of many problems, but the manager can call a maintenance tech sooner to drill down to the specific issue — versus an undetected abnormality, resulting in poor performance, unplanned downtime, or even more costly repair. The smart control system proactively protects the equipment and enables better use of maintenance resources by providing better direction to technicians.

Chapter five

Creating a simple interface solution for intelligent equipment

This stage of building out a smart motor control system allows for different scenarios to be addressed based on where the information is needed relative to the personnel involved. In other words, who needs to the respond and how will that person access the information.

What is the access method? An operator may only need to know the existence of a particular issue, but not all the details. The maintenance technician will likely want more specifics, so giving that person access to more detailed information will be necessary. A facility manager may desire a monthly summary. Smart motor control opens the door to access important information, but how that information is viewed will vary based on the need.

Here are a couple ways to create a simple interface solution for intelligence motor control:

Local: Pilot lights (most simple: "maintenance required" to specific alarm lights)

Local: Human Machine Interface (HMI) (simple but requires programming): Integrated HMI with touch screen for general display of status on the machine itself. HMI enhances the presentation of the information through graphs and charts.

Local: Advanced starter digital interface (simple, could be wired or Wi-Fi): Install a local Wi-Fi router in each cabinet (e.g., in a distribution center with many conveyors) to allow an operator or maintenance tech to locally access within the environment.

Local: Control room (via intranet, typically requires programming): Enable local intranet for the machine to be able to communicate to a main office (e.g., allowing a large grocery store to keep track of all electrical devices and equipment from a central, on-site location).

Remote: Cloud-based (more accessible to the personnel but requires programming and more cybersecurity consideration): Use this application when remote access is essential (e.g., in a pumping station in a rural environment with clusters of pumps over a 150-mile span). This solution enables the opportunity for remote monitoring services, as could be provided by the OEM or service contractor. This interface uses the cloud to allow authorized users to view important information about the equipment from any location with internet access. For security, the interface could be set up for different profiles (e.g., OEM/designer, commissioner, maintenance technician, operator), giving each the ability either to just view and/or change settings based on their role.

Local: Human Machine Interface (HMI)

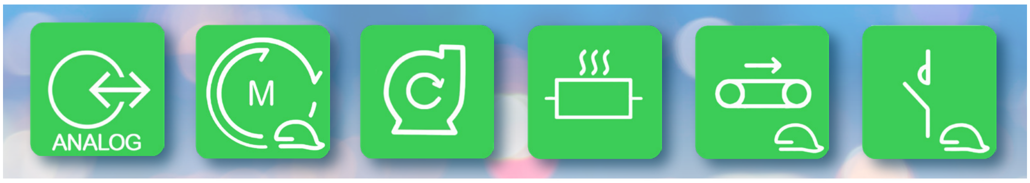
Remote: Cloud-based

Chapter six

A practical smart motor control example: TeSys island

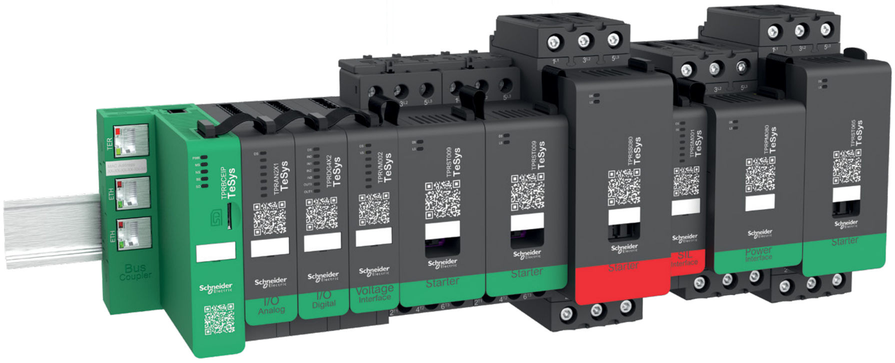
TeSys™ island by Schneider Electric™ is digital multifunctional motor control solution designed to switch, protect, and manage motors and other electrical loads up to 40 HP in an electrical control panel. It provides data for higher machine efficiency and ease of servicing, and it facilitates faster time to market.

The modular, multifunctional TeSys island provides integrated functions inside an automation architecture, primarily for the direct control and management of low-voltage loads. This system is designed around the concept of digital twins, also referred to as TeSys avatars. These avatars are the functional object representing a logical function of the physical module with pre-defined logic. They determine the configuration of the island.



The logical aspects of the island are managed with software tools, covering all phases of product and application lifecycle: design, engineering, commissioning, operation, and maintenance.

The physical island consists of a set of devices installed on a single DIN rail controlling loads and monitoring data and diagnostics information, and is connected together with a ribbon cable providing the internal communication between modules.



The external communication with the automation environment is made via a single coupler module, and the island is seen as a single node on the network. The other modules include starters, power interface modules, analog and digital I/O modules, voltage interface modules, and SIL interface modules, covering a wide range of operational functions.

Thanks to TeSys island's object-oriented approach, application selection and system configuration is simplified and engineering tasks are reduced, enabling a faster machine installation phase. TeSys island gives users access to device-related data for system diagnostics. In addition, TeSys island can be easily integrated into third-party automation systems and supports several fieldbuses (like EtherNet/IP and Modbus TCP).

TeSys island system overview

- The system manages motors and other electrical loads up to 40 HP
- Up to 17 modules and three bus couplers (up to 112 cm in length)
- One-click mounting on DIN rail and no need for control wiring on modules
- Eliminated control wiring thanks to full connectivity over fieldbus
- All adjustments and settings are digitized, no mechanical dials or dip switches
- Digital and analog I/Os available
- Different products compliant with international standards (IEC / UL / CSA 61010, IEC / UL / CSA 60947, GB/T14018)
- Only 20 commercial references for the complete system, including five standard motor starters and five SIL motor starters for functional safety systems as defined in IEC 61508, IEC 62061, and ISO 13849-1
- Energy monitoring at load level
- Cybersecurity embedded into the system (Achilles Level 2)
- Safe Stop TUV certified (Stop 0 and 1 with wiring categories 1 to 2, suitable for PL c, d (Performance Level) and SIL (level 2)
- Open connectivity thanks to EtherNet/IP, Modbus TCP, Profinet, and Profibus fieldbuses

TeSys island benefits for smart motor control

- Detect and solve issues before your machine stops
  - Minimize downtime, increase output
  - Enable faster troubleshooting thanks to the Operations & Maintenance Tool
  - Use operators and maintenance technicians more efficiently
- Gain better insight to the operation and performance of the machine
  - Plan maintenance instead of reacting
  - See energy usage to identify issues or help meet usage-reduction goals
  - Gain intel on how equipment is used
- Decrease time to project completion, helping improve project profitability
  - Design faster using the online configurator
  - Simplify programming using avatars to do common control operations in the bus coupler
  - Reduce setting configuration using avatars that pre-configure based on the application
  - Install faster by dramatically reducing the control wiring
  - Commission faster using included digital tools

Applications

Optimized and high-performance machines installed in:

- Food & beverage
- Material working
- Material handling
- Pumping
- Packaging
- HVAC & refrigeration

Use case: mining application

A company in the northwest uses conveyors for mining applications to move the mined material. If too much material is loaded onto the conveyor, the motor starts to overload. With traditional control, the overload relay will trip the affected motor in the long line of conveyors. That protects the motor from burning up, but a huge problem can occur when moving material runs into a stopped conveyor in a long line of conveyors. When one section stops, a material pileup can occur.

The traditional overload mechanism may not even get to a warning point until 115% of FLA and doesn't trip instantaneously. It responds according to a time-current curve: if the conveyor is running at two times the current, it might take about five minutes to trip, whereas if running at six times the current, it will trip faster (e.g., in 10 seconds).

With an intelligence motor control solution, the end user can detect when the current goes above the FLA. The machine builder can set an overcurrent alarm as a tripping event with relevant, actionable information. For example, "current is running higher than it should be and not changing anything operationally will lead to a trip." This information is enough to alert the operations upstream of the overloaded conveyor, prompting action to stop or slow the amount of material being placed on the conveyor section, and allowing the conveyor to clear the excess weight before carrying additional materials.

This intelligent approach to smart motor load management avoids one section stopping and causing material to run over.

Amp up your digital transformation!

Learn more about TeSys island intelligent motor control and protection.

About the author

Erik L. Barnes is an Offer Marketing Manager at Schneider Electric. He holds a bachelor's degree in mechanical engineering from Pensacola Christian College. He has held positions including applications support, product management for motor control products, UL 508A panel shop manager, and applications marketing. Over his 20 years of experience in electric motor control applications, he has published multiple articles, technical papers, and videos focused on control applications including UL 508A device applications, short-circuit current ratings, undervoltage conditions in motor control, and others. In addition to technical writing, Erik has led numerous training seminars and webinars. He has also led initiatives to develop tools that make it easier to select product in compliance with code requirements, including short-circuit current ratings and selective coordination. Erik has received award recognition for his work in education and product application tools. More information on his career and accomplishments can be found at www.linkedin.com/in/erik-l-barnes.

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