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On the road to smart machines — How OEMs can improve the energy efficiency of machines

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by the Smart Machine Group

Executive summary

While many original equipment manufacturers (OEMs) are aware of smart technologies to make machines more energy efficient, they are reluctant to make changes due to the perception that it will make their machines more expensive to sell. The constraints of cost reduction, usage of resources, and energy reduction are becoming key drivers in the industry as consumers require manufacturers to be more “green.” This paper demonstrates how incorporating sustainable design can add value to machines and differentiate OEMs from the competition.

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Introduction

Efficiency is one of the most important values in today's fast-changing environment and one part of this efficiency relates to energy efficiency. Worldwide demand for energy is expected to double by 2050. Growing concern for the environment is driving the emergence of more stringent energy-efficient regulations around the globe.
And the industrial sector is on the front line. The constraints of cost reduction, usage of resources, and energy reduction are becoming key drivers in the industry as consumers require manufacturers to be more "green." End users understand the new challenges and have developed strategies to reduce the energy for their production and become sustainable companies.

Machine builders and OEMs are now on the front line to design; they have to build smarter machines that innovate for this new demanding market. Automation solutions have already proven their effectiveness and benefits to reduce energy and resource consumption per product. In this way OEMs bring new added value to their equipment and a truly competitive advantage through this differentiation. The end users choose these new benefits in regard to their strategies. It is at the design level that all the benefits of an energy efficiency approach can be implemented. The following is a review of key highlights that can benefit the energy efficiency objectives of your customers and offer an advantage for your machines/equipment depending on their applications.

Fix the basics in machine design: Smart, energy-efficient automation devices and technology

Implementing the appropriate automation devices right from the start in your design can be a key source of improvement in the energy consumption of machines. Designing a more energy-efficient machine creates cost savings over the lifetime of the equipment. This lower cost can then be passed directly to end users, making your company more competitive.

Smart automation technologies already exist to optimize your machine design and you can fix the basics by:

- Choosing the right sized motors
- Using high-efficiency motors
- Choosing the right variable speed drives
- Choosing the right contactors and protective devices
- Creating more efficient motion control solutions
- Improving the enclosure's thermal efficiency
- Choosing the right automation devices, tools, or technologies (HMI, controller sizing, LEDs, etc.)
- Implementing the right automation architecture and its associated automation component

Sizing of motors

Industry and infrastructure consume more than 31% of the available energy in the world and electrical motors alone represent more than 60% of that energy consumption. All too often machine actuators are oversized (electrical motors, pneumatic actuators, etc.). This leads to machines that consume more energy than necessary, something that can easily be avoided through proper design. Applications need to be carefully evaluated to consider how robust and reliable a machine must be, as well as what future evolutions of the machine might be needed.

Small, simple motors are better ones than bigger ones. Experience shows that from an energy-efficiency perspective, using motors that are precisely matched to an application rather than simply using motors with "more than enough" power optimizes energy consumption. This basic recommendation can lead to an average savings of 3 – 4%. At the same time, it can impact the reduction/sizing of the power control system.

Better sizing brings cost reductions in runtime with some impact in lowering machine costs (see Figure 1).

Download our FREE software Motion Sizer, engineering tool for CAM design and power unit dimensioning.

For more information on why the choice of the motor should be the starting point in order to reduce the power demand, see White Paper, "Energy efficiency of machines: the choice of motorization."

Figure 1

Motor's energy bill = motor cost x 100

Beyond the investment, the key point is to secure an efficient motor control.

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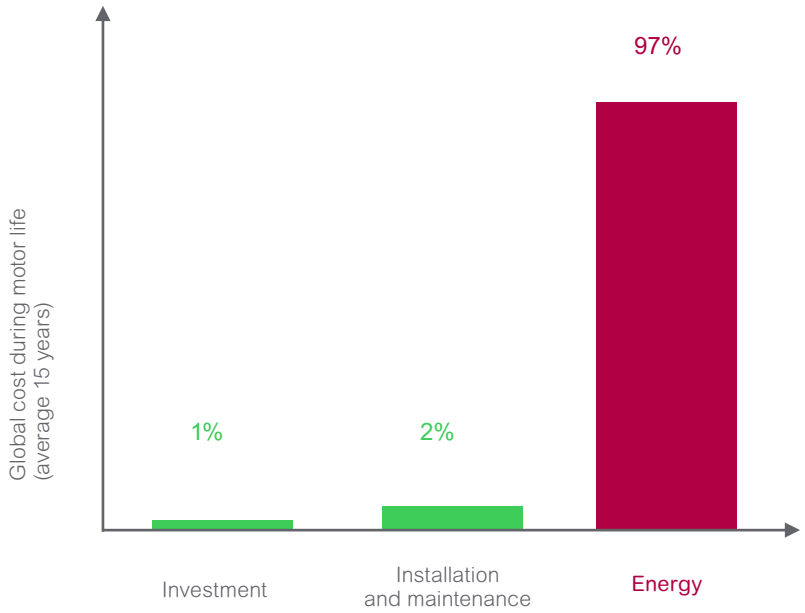


Using high-efficiency motors

Industrial motors, a major global consumer of electricity, are one of the prime targets of the new regulations and standards. The transition to IE3 premium efficiency motors is underway, raising challenges for businesses. Legislators are addressing energy efficiency in the industrial sector with new regulations. Since January 2015, the Directive has required most direct online motors to be of the IE3 premium efficiency class. Recent market research by global information company IHS revealed the continued gradual market penetration of IE3 motors. Because motor regulations are not strictly enforced, the transition is expected to remain gradual. Despite demand from customers for IE3 motors and, more generally, energy-efficiency solutions, some OEMs continue to offer IE1. As customers begin to include IE3 motors in their requirements, the market will inevitably shift toward these motors.

High-efficiency motors have proven their effectiveness and typically have a payback period of only one to two years. The new standard IEC classification for high-efficiency motors specifies four categories (see Tables 1 and 2). The additional benefit is that the longer machine life of high-efficiency motors contributes to sustainability — and a benefit of about 10% energy savings can be expected (see Figure 2).

Table 1

New international efficiency classes of motors.

New international efficiency classes of motors	
The new EN 60034-30:2009 defines the following efficiency classes of low-voltage, three-phase asynchronous motors in the power range from 0.75 kW to 375 kW. (IE = International Efficiency)	> IE1 = Standard efficiency (comparable to EFF2)
	> IE2 = High efficiency (comparable to EFF1)
	> IE3 = Premium efficiency

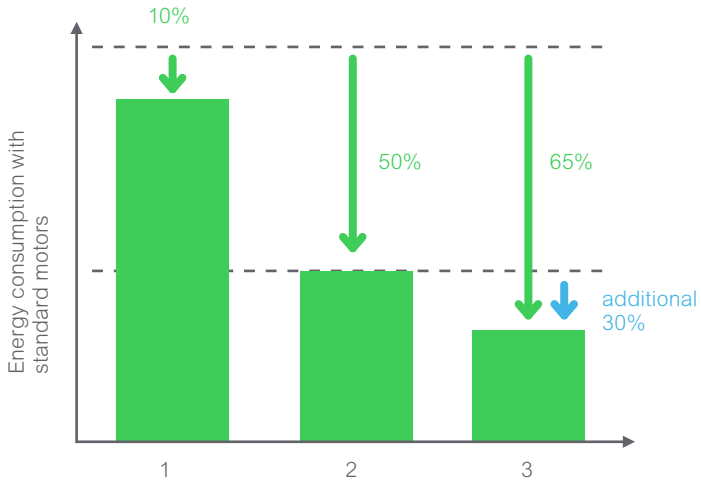
Table 2

Regulations and standards in other parts of the world.

Regulations and standards in other parts of the world	
United States	In the United States, the National Electrical Manufacturers Association (NEMA) has rolled out an initiative similar to what is being seen in Europe with the NEMA Premium® Motors program, a label equivalent to IE3 premium efficiency. NEMA Premium motors account for an estimated 20% of market share in the U.S. (2015). High prices and low ROI are slowing the widespread adoption of these motors. Their design disruption is lower than in Europe due to their de facto savings of 20% thanks to the frequency of 60 Hz in addition to their longer frame (NEMA size). Consequently, they have a lower rise of the inrush current in comparison with the European 50 Hz asynchronous motors.
India	The Bureau of Indian Standards has released updated energy-efficient motor standards (IS12615:2011) that align with EU regulations: “The efficiency performance values of motors under the scope shall be IE3 only and shall be effective from 31 January 2014. However, when these motors are used with variable frequency drives, they shall conform to IE2 values of efficiency.”
China	The Chinese government published standard GB18613 setting the energy-efficiency requirements for general purpose motors. It was updated in 2012 to more closely align with IEC 60034-30-1.
Other countries	Australia, Korea, Brazil, Mexico, Taiwan, Costa Rica, Israel, and New Zealand are among the other countries that have taken steps to improve motor efficiency through more stringent regulations.

Figure 2

Design your machines with optimized motor control: Higher-efficiency technology*



1. Use a motor with higher efficiency	2. Use a variable speed drive to control your motor	3. Use a Servo drive and synchronous motor
Up to 10% savings	Up to 50% savings	Up to an additional 30% savings (compared to speed drives in positioning application's modular distribution)

* The benefits mentioned are specified for each point and are not cumulative. Application examples have been measured in real cases.

Thinking about motor starters: Variable speed drives are a must

For applications with variable loads, the use of speed drives can bring immediate benefits and up to 50% in energy savings (pumps, ventilation fans, and compressors are obvious applications).

At the same time, any application that requires repetitive starting, the choice of speed drives over conventional contactors, limits starting current and therefore reduces losses and load peaks. The instant benefits for end users, such as cost savings in their electrical bill, can be highlighted by a payback of less than one or two years.

Some applications, such as hoisting and lifts, can benefit from regenerative devices like regenerative drives.

Choosing the right contactors and protective devices

When using contactors, some simple choices can significantly reduce power consumption.

Today the use of low-consumption contactors or contactors for specific functions (i.e., latching relays), in a combination of properly selected contactors (such as TeSys™ U motor starter) can reduce power consumption up to four times thanks to the lower energy loss attributed to fewer connections.

In fact, TeSys U motor starters dissipate 75% less energy compared to traditional motor starters. This is achieved by the reduced number of power contacts and by the very low energy consumption of the control circuit.

Acti 9™ protection and control systems combined with the Smartlink communication system are compatible with any Energy Management and Control System architecture. These systems unite basic control with optimum protection to easily manage energy-efficient solutions in any environment using the flexible, reliable, and easy-to-use Modbus communication system.

Using TeSys circuit breakers, contactors, and thermal relays ensures optimal energy efficiency for your installation and compliance with the latest regulations.

Choosing the right devices and knowing which devices to use in combination with a contactor is crucial. To select the right circuit breaker and overload relay, you should:

- Follow the recommendations of your motor protection manufacturer.
- Avoid overdimensioning cable sections.
- Verify that the electrical characteristics stated by the motor manufacturer are in accordance with the motor starters used.
- Verify the coordination of the motor starter components if these are selected separately, without using a recommended coordination tables.

Schneider Electric™ TeSys circuit breakers and thermal relays have undergone magnetic, electrical, and thermal endurance testing in laboratory conditions to ensure their compatibility with IE3 motors.

For more information, see White Paper "Energy IE3 premium-efficiency motors: choosing the right motor control and protection component."

Creating more efficient motion control solutions

Motion solutions enable the mastering of movement. Every time there is a transfer or movement, motion technologies (servo motors, motion controllers) bring incredible advantages. When associated with synchronous motors, they bring significant energy advantages.

Besides the key advantage of improved performance of up to 60% in energy savings, faster machine cycles increase output and more precise positioning means fewer defects.

The technology of synchronous motors (yield of 95%) outperforms asynchronous motors. The calibers of motors are smaller as well.

Synchronous motors provide energy-efficiency benefits of up to 10% compared to asynchronous motors, thanks simply to the technology (no losses in rotor).

Motion solutions substitute as well as other technologies and are bringing significant advantages in terms of energy efficiency:

- Mechanical for synchronization of movement (cams, gears, etc.)
- Pneumatics and hydraulics; e.g., pneumatic substitution reduces energy use as losses and leakage are significant and seldom avoidable

Improving the enclosure's thermal efficiency

Temperature, humidity, and dew point all affect the performance of your electrical and electronic enclosures. The problem is, unless these environments are sized properly, thermal conditions will compromise reliability, safety, and efficiency, as well as the lifetime of your panels.

Temperature directly affects the reliability and service life of electric — and especially electronic — equipment. Indeed, when devices and installations in enclosures fail or malfunction, it's almost always a thermal issue. Determining the relevant thermal management in control panel enables limiting thermal pollution to environment.

- Machine reliability (longer lifetime for electronic equipment, reduced breakdowns)
- Potential machine cost savings (suppression of oversized cooling systems)

The ClimaSys™ range enables a relevant thermal management of electrical switchboards and control panels in any demanding commercial and/or industrial environment. ProClima software processes a range of specified thermal data in order to propose the right thermal management choice to match the environment and electrical/electronic devices installed inside your control panel.

For more information, see Technical Guide: How to reduce damage to components through effective thermal management.

Choosing the right automation devices, tools, or technologies (HMI, controller sizing, LEDs, etc.)

- HMI (graphic terminals and panels) — The management of backlights in HMI panels can save 65% of the power they consume, for example by powering off the display when the machine is in idle mode (e.g., Magelis™ XBTGT).
- Use of LEDs — LED technology offers a low-consumption alternative to incandescent lights in pushbuttons and indicator lights and should be applied systematically.
- Controller sizing — Controllers that are properly sized to the application at hand will help reduce energy consumption.
- Power factor correction — In order to compensate for reactive power, and eventually eliminate it, it is best to be positioned closer to the source. This will optimize the energy usage of the machine and benefit end users to avoid penalties and pollution in their electrical networks.

Tested, Validated, Documented Architectures

… to quickly build an automation solution.

Ready to use for optimum result:

- Predefined architectures and bill of materials

Open and flexible:

- Flexible machine control: Embedded intelligence in devices with SoMachine™ software
- Evolution of cabling connectivity (hardwire or network)
- Your know-how preserved (other products, etc.)

Ready to be customized:

- Customized tests to validate your own configuration by experts

Implementing the right automation architecture

The automation control system also consumes power (not at the level of actuators), but optimization can be implemented by picking the right offer and making the right decision.

Depending on the application, the right automation architecture can have a favorable impact on energy consumption of the overall control system. For example, a decentralized architecture can double the consumption of a centralized architecture.

Of course, depending on the size of the application, as well as safety and performance criteria, the choice of a decentralized architecture is sometimes necessary.

Also, optimizing the number of 24 V power supplies can induce energy savings up to and including their associated losses.

State-of-the-art automation solutions integrate controllers, monitoring systems, HMIs, and networks into a seamless solution that makes it easy to get a complete view of your energy usage. With smart automation architectures based on open standards, your processes are sustainable for the long term and scalable to fit your exact needs and achieve productivity.

To learn more about Tested, Validated, Documented Architectures, click here.

Optimize your machine design

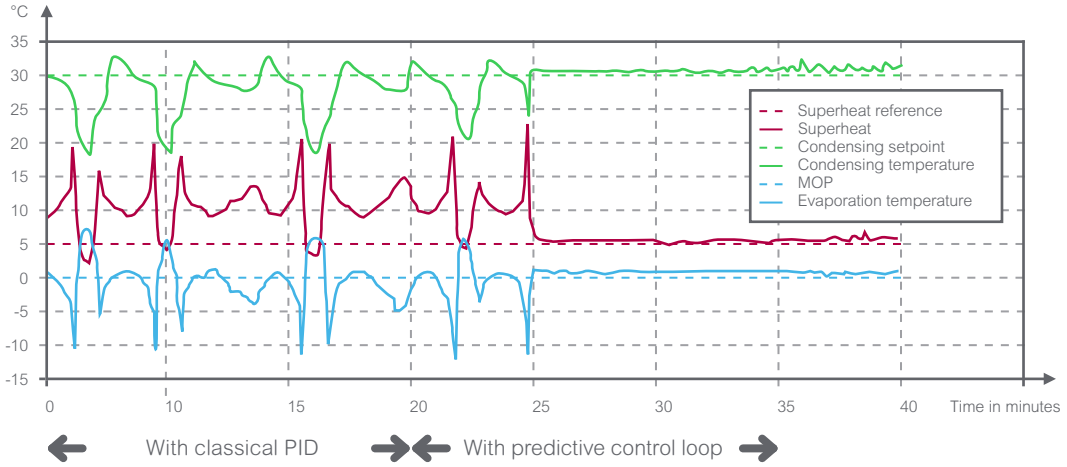
Automation is a key opportunity for achieving energy efficiency; the capabilities available through programming provide many new possibilities. New algorithms, for example, have already proven themselves and can be found in application libraries.

Predictive Control Loop: A new source of energy efficiency

The classical PID can be out-performed by a Predictive Control Loop when algorithms are integrated into the programming system, with potential savings of more than 10% (see Figure 3).

Figure 3

Advanced control functions in HVAC applications have been measured recently bringing more than 10% in energy efficiency compared to PID regulation.



Monitoring operating modes and status through automation

End users do not always use the full capacity of their machines and equipment, depending on their production objectives. Some key areas are frequently stopped intentionally in order to activate only the needed resources. These techniques can be efficiently applied in conveying, such as becoming active only when the load arrives rather than running continuously.

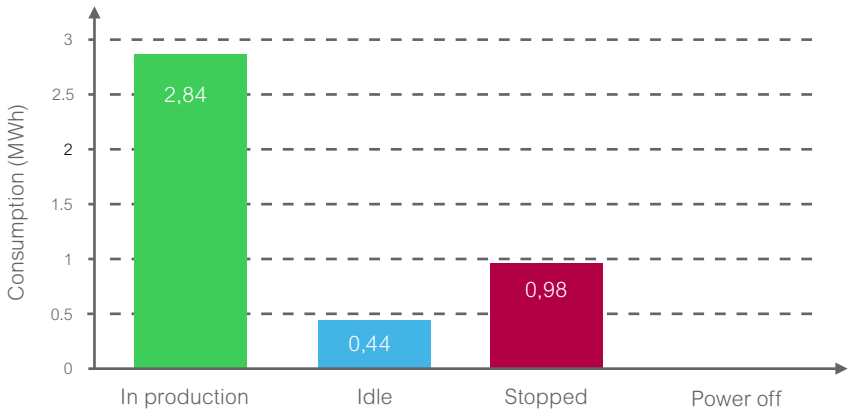
Stopping, idling, or on-hold functions are deactivating the actuators and should be integrated in the programming to generate further energy efficiency for the benefit of end users. Studies have demonstrated that machines are rarely in production 100% of the time, and it is estimated that consumption could be reduced by nearly 37% if machines were properly managed during these idle periods, for example, by simply powering them off.

Safe stopping and restarting conditions should also be considered as a source of energy efficiency, such as avoiding keeping the control system and communications bus under power when switching off the machine. This is possible when parameters are saved upon stopping and re-enabled upon restarting under the previous state. Sometimes the solution is not completely obvious, such as for constraints on safety or quick restarting of the line; end users preferably choose to maintain the control system under power.

Some optimization and benefit can be reached as well in managing the starting of machines. By using sequential starting you are able to minimize the starting current and avoid peaks that generate penalties by the power utilities in some countries.

Figure 4

Active energy management through automation. Up to 37% in savings realized in an automotive production line through the proper management of control systems when machines are idle or stopped.



Optimizing energy efficiency in dedicated applications

- Hoisting: Save 60,000 kWh every year in hoisting; Container crane with regenerative solutions

  Example Container crane hoisting application, 250 kW load:
  - Cycle time: 5 minutes (1 minute lifting, 1 minute lowering, 3 minutes handling)
  - Operation time: 8 hours/day, 200 days/year
  - Energy cost: €0.12/kWh
  - Drive investment for resistor braking: €23,000
  - Drive investment for Active Front End (AFE) solution: €34,000

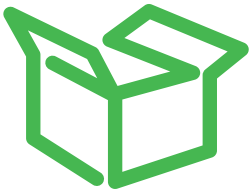
  Results:
  - Energy consumption with resistor braking: - 100,000 kWh/year = €12,000
  - Energy consumption with AFE: - 40,000 kWh/year = €4,800
  - Energy and cost savings: 60.000 kWh/year = €7,200
  - Payback time: ≈ 1.5 years

- HVAC: Save up to 30% on air-cooled chillers with dedicated solutions;
  Energy savings by adjusting fan speed to changes in external air temperature

  ATV212 drive + Modicon M171/172 controllers using the floating high pressure control with variable speed drive function block:
  - Up to 20% less energy than On/Off condenser fan controls

  Energy savings by optimized electronic expansion valve control:
  - Due to the implementation of advanced “superheat control” function on Modicon M171/172 controllers for a chiller’s electronic expansion valve control
  - Up to 5 °C superheat setpoint reduction equivalent of up to 10% less energy than standard superheat control with higher set point

  For more information, see White Papers “Energy savings in commercial refrigeration equipment - High pressure control” and “Energy savings in commercial refrigeration equipment - Low pressure control.”



- Packaging: Improvement in terms of consumed watts per manufactured unit, enabling up to 30% energy savings compared to traditional machines.

  Calculate machine’s energy footprint:
  - Simulate the energy requirements for every component with PacDrive solution for motion centric machines
  - Calculate a dynamic, machine-speed-dependent energy footprint by using

Application Function Blocks (AFBs) — all without connecting a single motor or other component

- Monitor the current measurement results with integrated power meters (Energy Dashboard)

Comprehensive consulting service:

- Identify the parts of equipment that are “power vampires” by using the Schneider Electric consulting service and working with experienced engineers equipped with state-of-art measurement technology.
- Review options for reducing high standby-energy consumption. By implementing standardized PackML-compliant operating modes, PacDrive has created the most important prerequisites for this process.

Technology for energy-efficient machines:

- With tools such as ECAM, PacDrive lays the groundwork for energy-optimized motion design.
- AFBs such as “Intelligent line shaft” create additional optimization potential. PacDrive incorporates high efficiency servomotors with efficiency factors greater than Class IE3, servo drives with DC bus sharing.

- Pumping: Up to 20% productivity increase by using variable speed drives.

Energy management reduce operation and energy cost:

- Innovative power technology
- Embedded harmonic mitigation as standard (THDi = 48% @ 80% nominal load)
- Regenerative solutions
- Integrated accurate (<5%) power measurement

Intuitive built-in pumping functions make process safer and more efficient:

- Management of the pump system curves
- Dedicated pump functions (Jockey pump, Pipe Fill, Booster, Level control, etc.)
- Pump protections functions (Dry running, High Flow, Low flow/Noflow, etc.)

Accurate diagnostics and remote services to anticipate system failures and to take action in real time:

- Dynamic QR code
- Predictive maintenance features (wear and drift detection)

For more information, see White Paper: “Smart Pumping: A New Way to Address the Worldwide Water Distribution Crisis.”

Measuring and monitoring energy consumption

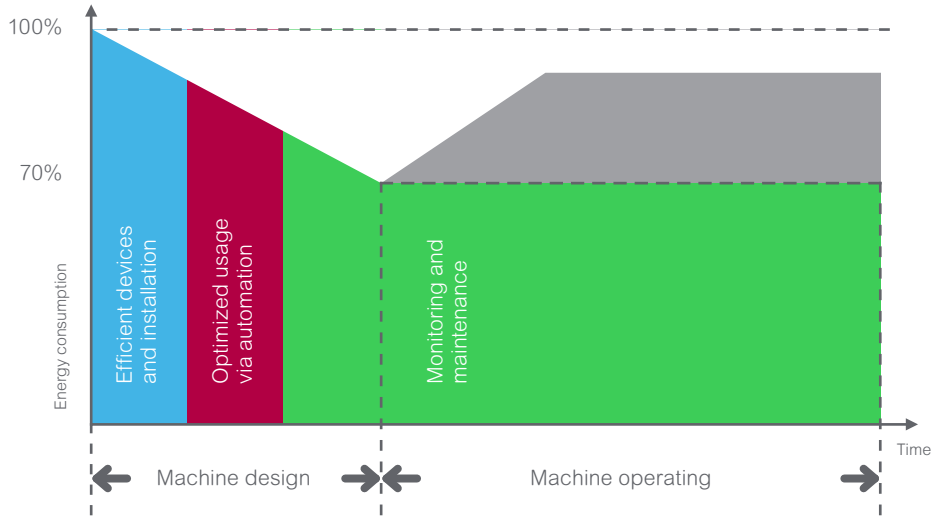
Companies that have a knowledge and understanding of their energy consumption through energy measuring and monitoring show increased productivity, improved employee engagement, and meet significant competitive advantages. In order to improve the industrial energy efficiency, energy consumed has to also be measured locally, in real time, and it starts with the devices and machines. The increasing smart automation within machines and factories can provide better visibility and efficiency from top floor to shop floor.

The level of machine monitoring enables preventive maintenance to avoid component failure and associated downtime or damage to the machine or components. It also allows for maintenance to be scheduled in order to minimize the impact on production while increasing business opportunities for value-added services.

Monitor and control during lifetime

Experience shows that an active approach to energy efficiency will help bring an additional 8% of savings via early detection of any discrepancies in the operation or ongoing life cycle of a machine. Operators, maintenance personnel, and production management teams can all take quick action to alleviate any conditions that might be negating the machine's energy efficiency.

Figure 5
Monitor and control during lifetime



Electrical signature of machine: Measurement

This basic measurement can be considered an "electrical signature" of a machine and can become the benchmark for future improvements and improved machine efficiency. In addition, it is a strong benefit for the end user's strategy.

This can be achieved quite simply today, such as with the Compact NSX Micrologic™, which has the capability to measure incoming power, or by the monitoring of power through a separate power meter, such as the PM800.

Immediate advantage to user's awareness and improvement are the key benefits: Using a power measurement devices and treatment of the machine consumption.

Machine energy libraries and dashboard

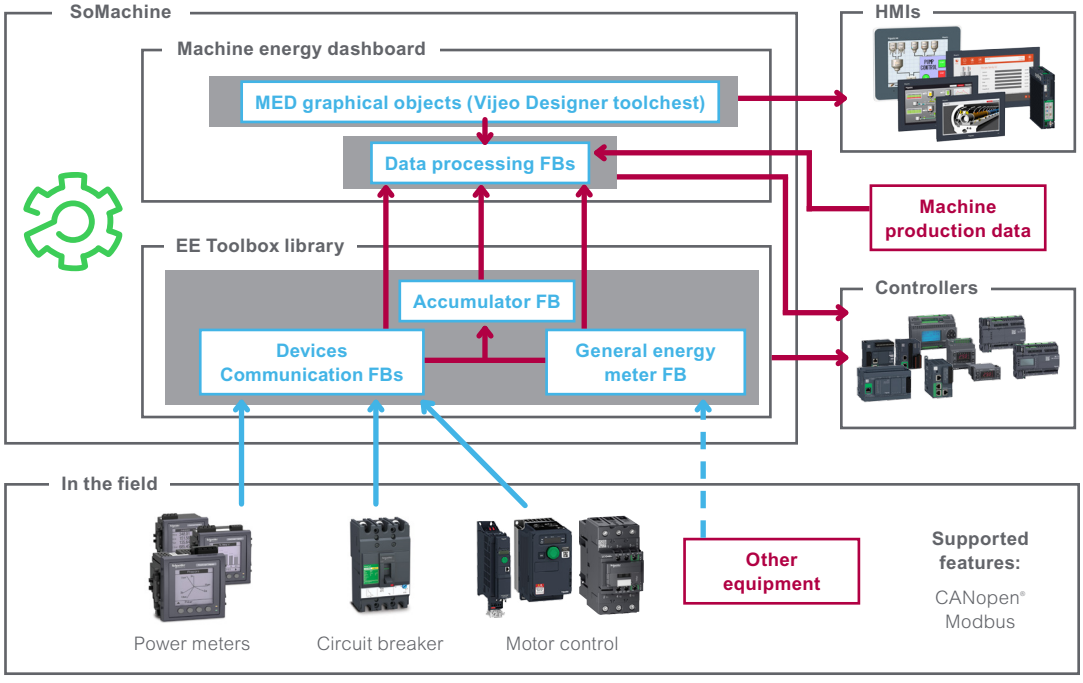
The machine energy-efficiency suite of tools provides an easy-to-use and comprehensive methodology to monitor relevant energy indicators by combining energy and production information. Monitoring of energy consumption allows relevant users to understand and therefore optimize energy usage by initiating production plan adjustments and behavior changes that improve the efficiency of the machines.

SoMachine, the OEM solution software from Schneider Electric, provides function blocks dedicated to the collection of energy information from the measures of central, electronic equipment (variable speed drive, servo motor, etc.). Information is used by some function blocks dedicated to providing indicators that track the relevant information by correlating the energy measurements (active power, energy, power, etc.) with the mode of operation of the machine (RUN or STOP for example) or unit production. All harvested indicators can be used on an HMI with predefined graphic objects provided with SoMachine and Vijeo™ Designer.

Measuring and monitoring energy consumption is crucial to manufacturing operations, as they are one of the major consumer of energy in the world. For the manufacturing industry, tracking and reducing energy consumption is no longer optional, that's why it could be interesting to consider the energy management aspects as part of the traditional Overall Equipment Effectiveness (OEE) methodology … with this new KPI, the OEE could become OEEE (Overall Equipment and Energy Efficiency).

Figure 6

The following figure depicts the interaction of the elements of the basic energy efficiency monitoring methodology.



Conclusion

As seen by the new design and introducing new smart technologies, OEMs are able to bring new values and contribute strongly to the sustainable approach that end users are now implementing. Automation and control functions are bringing a wide range of possibilities to improve energy efficiency and reduce waste, therefore should be considered systematically. The active approach to energy efficiency gives end users the possibility to optimize the energy consumption of their production investments for both immediate and long-term savings.

An energy-efficiency approach naturally has a cost for the OEMs; new design and new technology integration, as presented in this document, would probably impact the final cost of the machine, which could be estimated in less than 10% depending on the application. Today, energy saving has become a key decision factor for end users. This is a new differentiation opportunity for OEMs in a very competitive market; to bring new benefits for its customers, less energy consumption by unit produced, less waste, better quality, and more performance with an ROI in less than two years.

Schneider Electric is committed to sustainability and helping OEM customers build more energy-efficient machines. As a pioneer in smart automation technologies, Schneider Electric also makes it easier for you to offer your customers safer, better connected, more flexible, and more efficient machines. We simplify the integration between products, machines, and processes to boost business efficiency and sustainability, both today and tomorrow.

Acknowledgements

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