Energy Saving Designs in Factory Automation Equipment

By: Paul Webster
Engineering Manager
FANUC FA America

Introduction

The ultimate goal of utilizing factory automation is to improve productivity while decreasing downtime which ultimately reduces overall costs. However, the overall equipment effectiveness of factory automation beyond its production ability has been largely overlooked. Rapid increases in energy costs have begun to focus more attention to reducing energy consumption. Innovative manufacturers today design factory automation equipment that goes hand-in-hand with energy savings, production performance and reliability factors during the design phase.

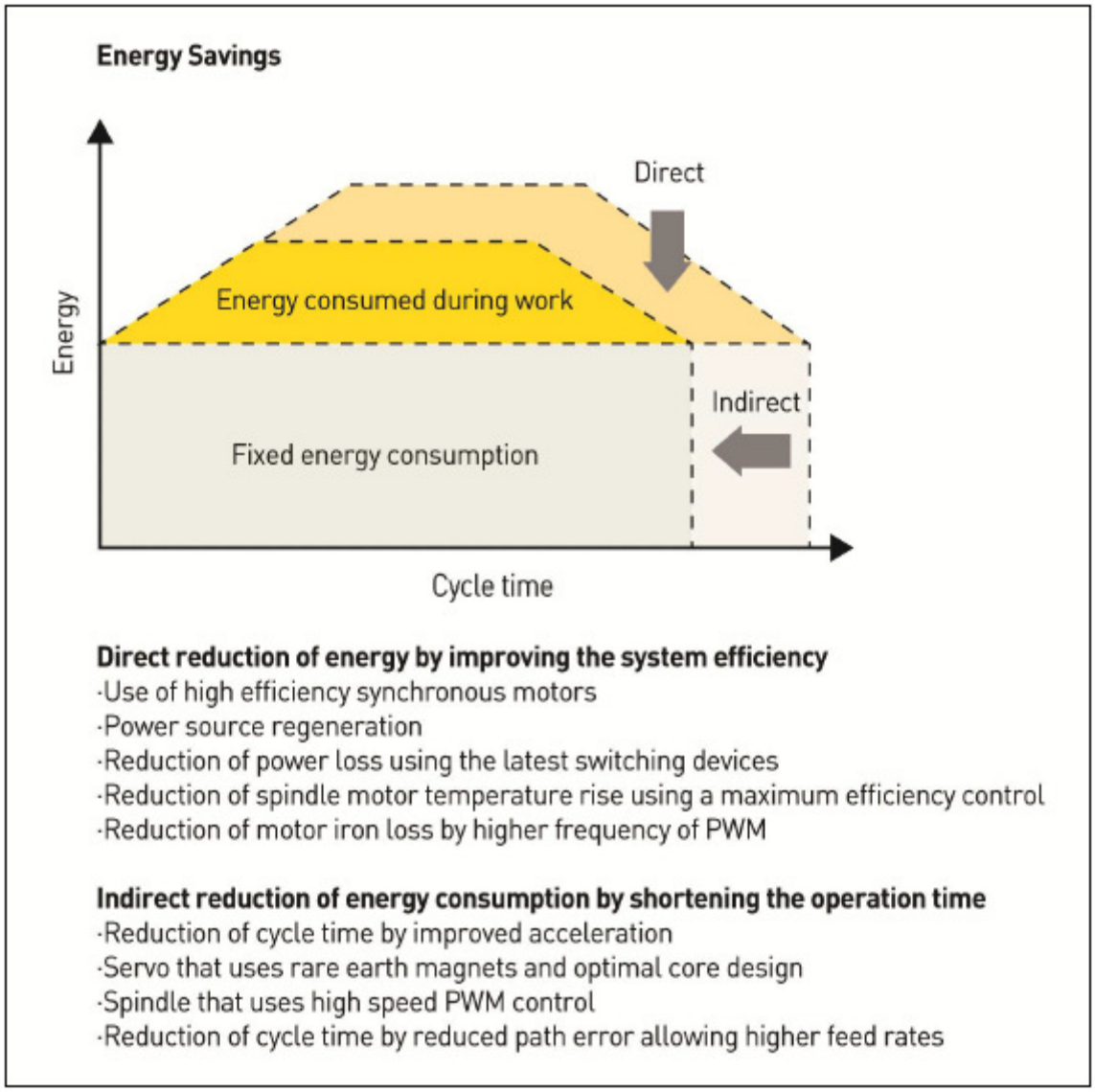
For example, electrical energy reduction in electrical motors can be achieved with energy efficient servo and spindle systems. Due to the fact that electric motor driven equipment accounts for 64 percent* of the electricity consumed in the U.S. industrial sector, this would impact a large group of manufacturers. In fact, these systems consume 290 billion kWh per year*. The energy cost needed to operate machinery throughout its useful life can easily exceed the original equipment cost. The use of energy efficient motor systems can greatly reduce the cost to operate this equipment.

Energy Saving Designs

Reducing the energy consumption of electric motors is broken into two categories.

1. Direct energy consumption: energy consumed while performing work
2. Indirect consumption: fixed energy consumed regardless of the operational state

Reducing the direct energy consumption requires enhancing the system efficiency, while reduction in indirect usage requires reductions in the cycle, ancillary and latency times.

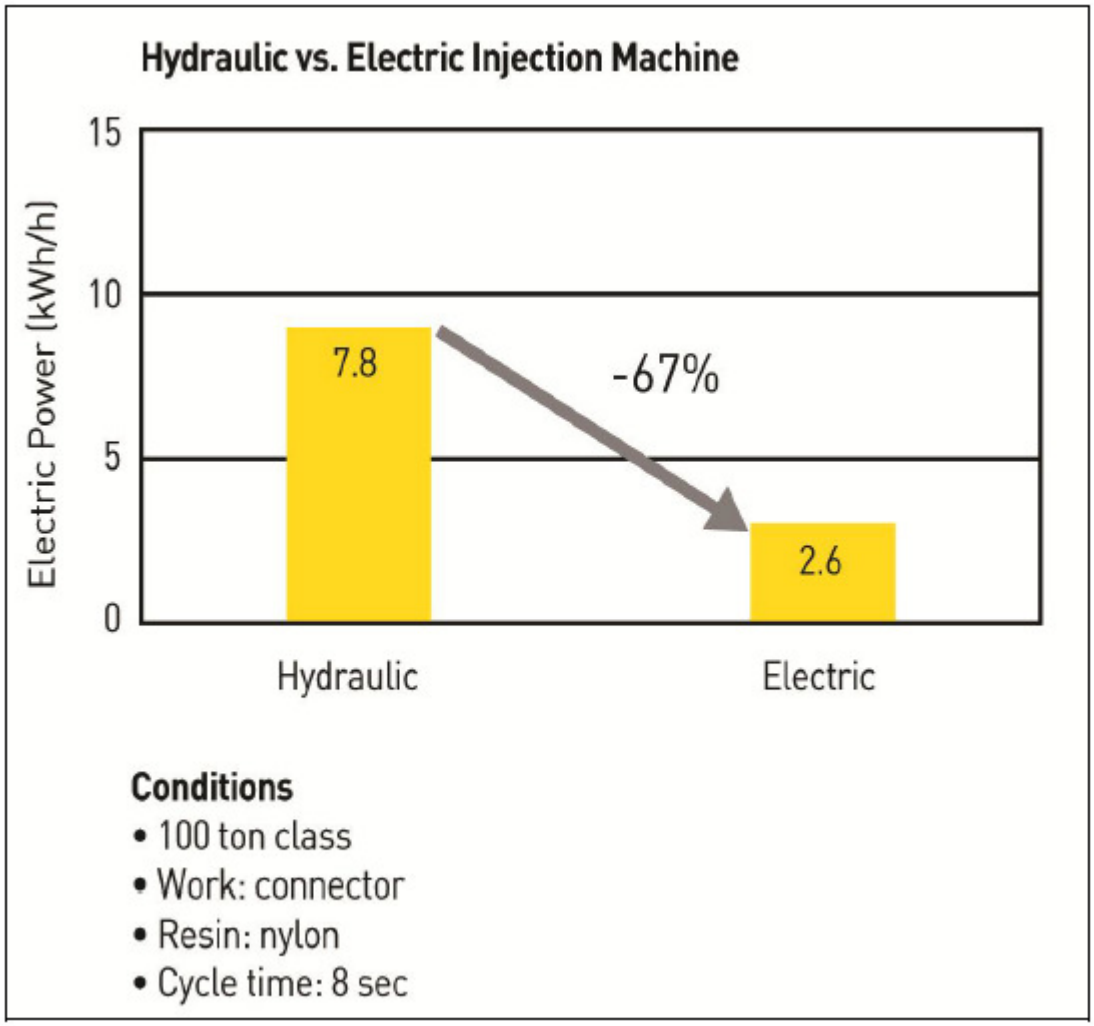


Reduction in Direct Energy Consumption

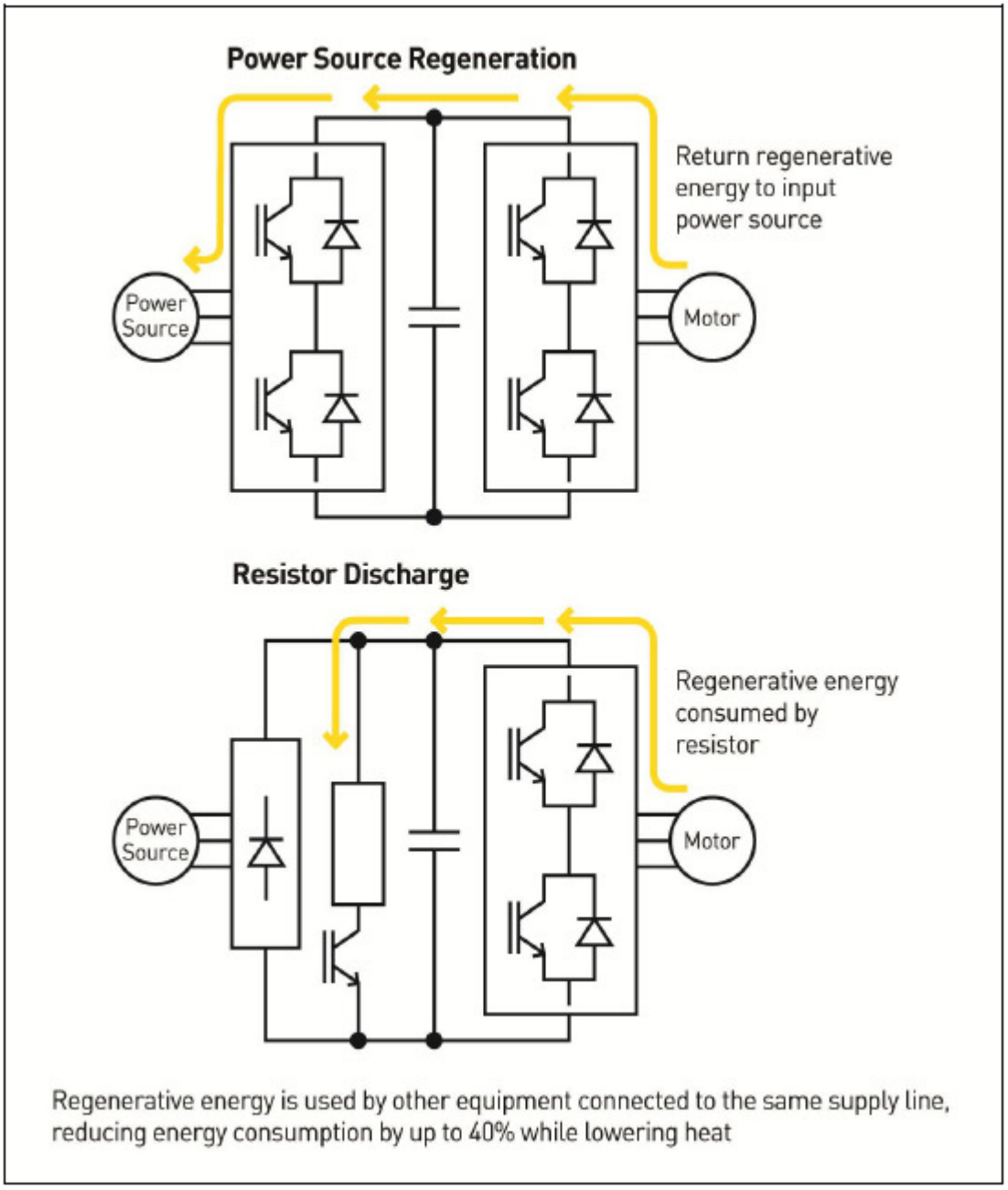
Energy efficient electric motor systems

Direct energy consumption is the energy consumed during the production cycle. It is the energy needed to do work. Improvements in this area require improvements to the drive systems and machinery selected. In industrial machines the selection of energy saving equipment is typically done during the design phase but in many cases can be retrofitted later onto aging machinery.

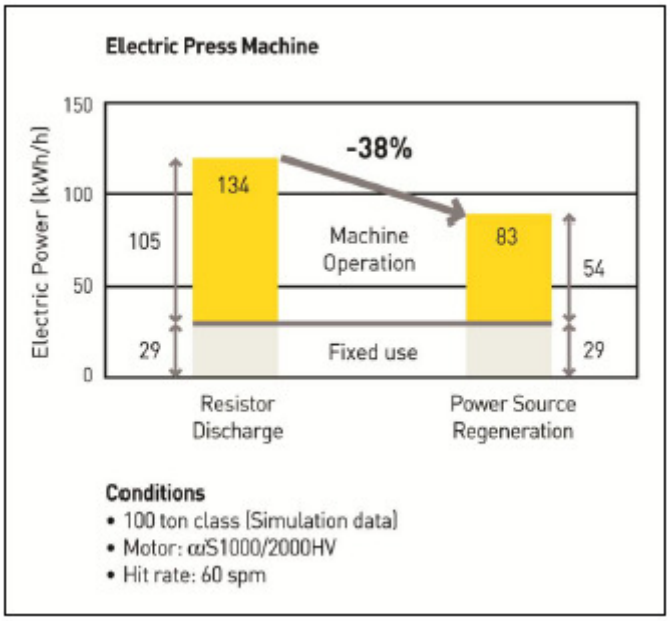
One of the most direct ways to reduce energy consumption is to only run motors while the operation is in cycle. Industrial machines using hydraulics or mechanical systems driven by induction motors require stored energy to assist them in performing the work. Since these systems cannot switch on and off quickly and are not easily controlled, they are forced to remain on while often at constant speed. The large power output of a synchronous motor allows for the motor to be idle when not in process - significantly reducing the power consumption. Replacing inefficient induction motors or hydraulic systems with modern permanent magnet synchronous motors is often the first step.



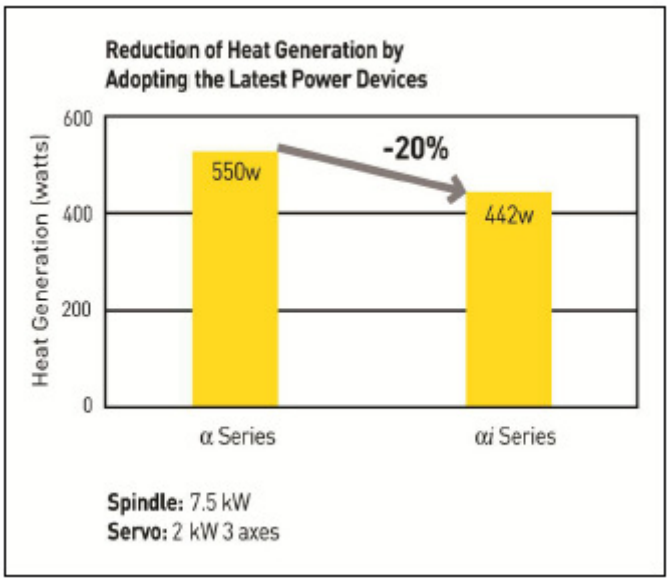
Implementation of power source regeneration is another excellent means of reducing the power consumption of an electric motor system. During deceleration of an electric motor it will act as generator and energy is put back into the system. In a conventional system, energy is sent to a discharge resistor which dumps that electrical energy in the form of heat. That waste heat is non-recoverable. By contrast, power source regeneration returns electricity to the supply line to be used by other equipment. The electrical energy is recovered and waste heat is greatly reduced.



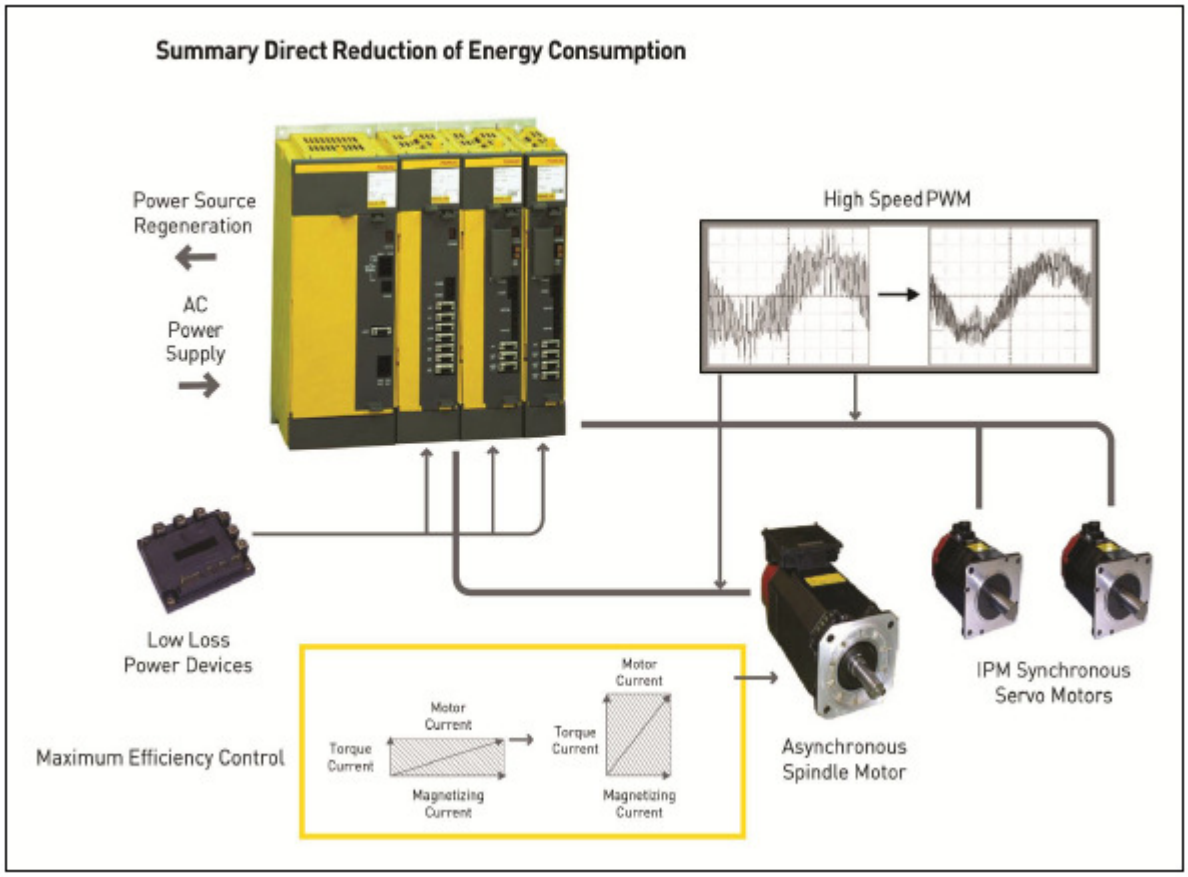
Power source regeneration requires a drive system with an intelligent power module that can sense the flow of current and switch accordingly. When used, the effects are significant. Implementing a servo driven system utilizing drive amplifiers with power source regeneration can see a savings of 30% to 40% in electrical power consumption.



Pulse width modulated (PWM) amplifiers provide an excellent control method for electric motors in automation equipment. Rapid acceleration with precise speed and current control is possible but there are always switching losses when using a PWM drive system. These losses translate into waste heat generation. Using the latest generation of power devices will increase controllability and reduce the heat loss. Reduction in heat loss directly equates to electrical energy savings.



Having drive amplifiers and software features matched to the motors and mechanical system selected also contribute to the direct reduction in electrical energy. When utilizing an induction motor, an advanced control system can optimize the firing angles so that the optimum torque is produced for a given current. Matching the current contribution of torque and magnetizing will lower heat loss within the motor but requires dynamic control. Using fast switching transistors and an increased PWM rate will lower iron losses in both permanent magnet and induction motors. Reduction in heat and other losses within the motors by using the latest power devices and control systems positively contributes to increased performance and reduced energy consumption.

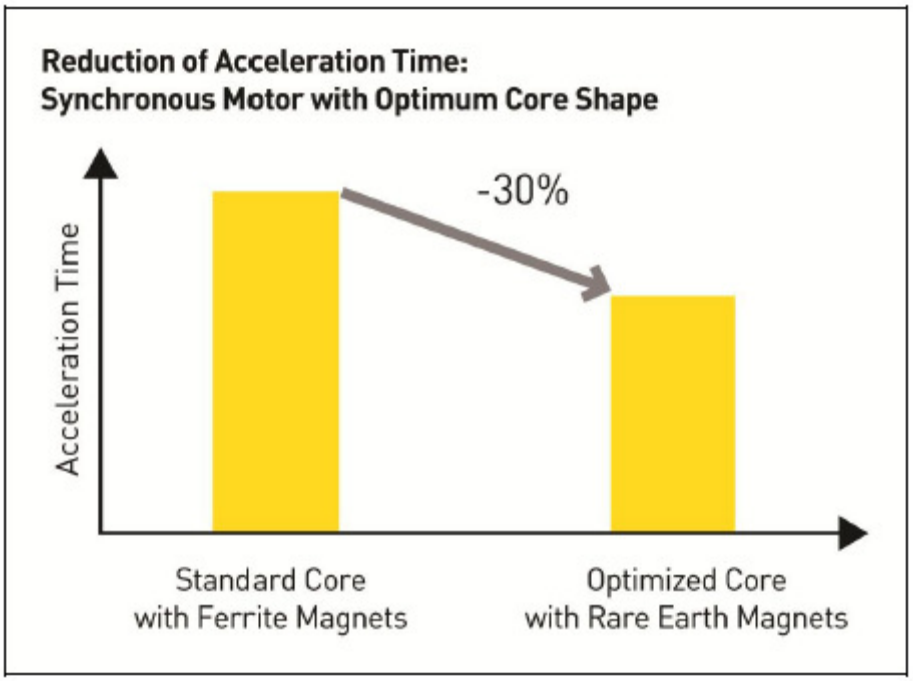


Reduction in Indirect Energy Consumption

Decreased cycle times lower energy usage

Indirect consumption is often overlooked when related to energy costs associated with the loss of production. Optimizing cycle times by improving acceleration and increasing the movement rates will result in increased productivity. However, this will also reduce the energy consumed. Reducing the time required for a motor to accelerate can provide a vast improvement in the process cycle time. In order to reduce the cycle time, the motor core shape must be optimized, inertia reduced and motor control matched

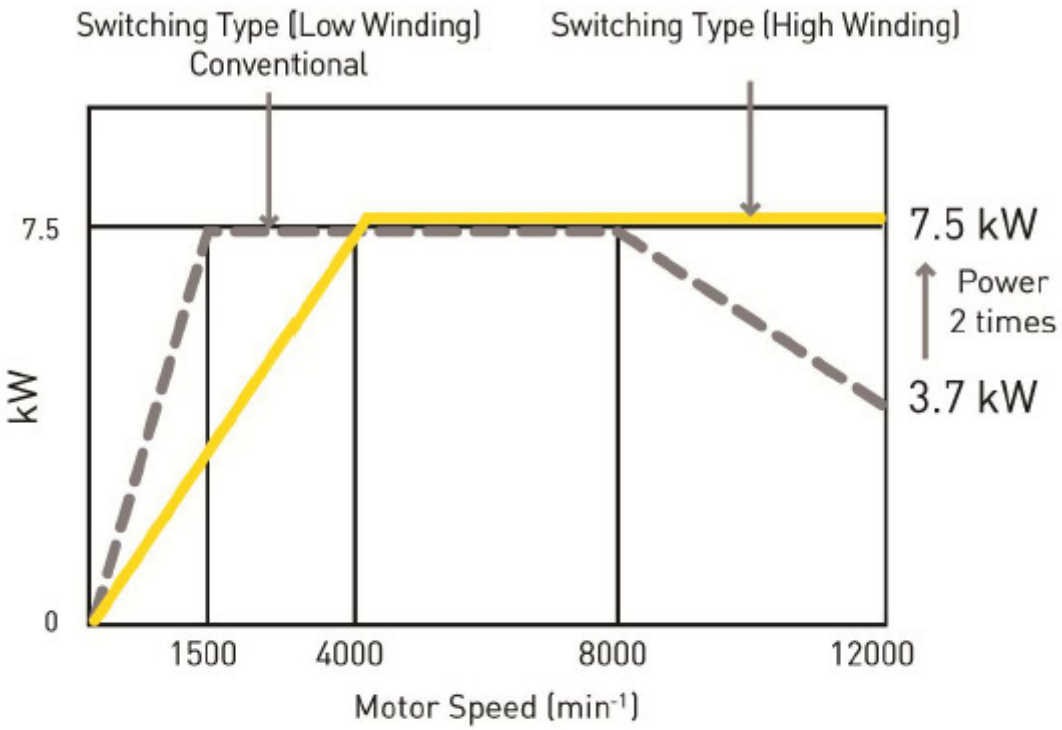
closely to the needs of the system. Using permanent magnet synchronous motors provide high power density and excellent acceleration. They are best implemented in high torque, high acceleration but lower RPM applications. Optimizing the core shape can involve utilizing rare earth magnets to increase power density while decreasing inertia and an IPM (internal permanent magnet) rotor shaped using finite element design methods to match the needed motor performance.



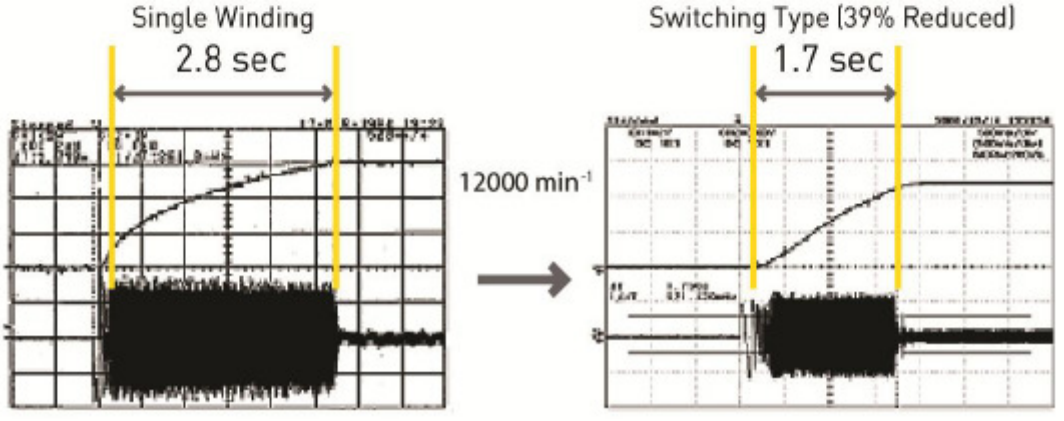
Fixed energy consumption includes all the fan motors, pumps, lights, etc. involved in the process. Reduction of the fixed value requires reduction in the time or amount of machines needed for production. Reducing the acceleration time and increased per machine speeds fills these requirements.

An induction motor with a wide constant power band can accelerate rapidly to a very high RPM. The design limitations of an induction motor make it difficult to have a low base speed needed for high initial torque and a wide constant power range to continue acceleration to high speeds. Dual winding motors have the capability of producing this very wide power band. The ability to switch windings based on motor needs enables one motor to perform like two. A low speed winding enables very high torque at lower speeds but past the constant output range the power drops off. Switching to the high-speed winding enables the constant power range to be extended to maximum speed, enabling rapid acceleration. The cycle time is reduced by rapid acceleration and often times a smaller motor size is required due to its wide output range enabling further environmental improvements in reduced energy and material usage.

Reduction of Acceleration Time Using Dual Windings

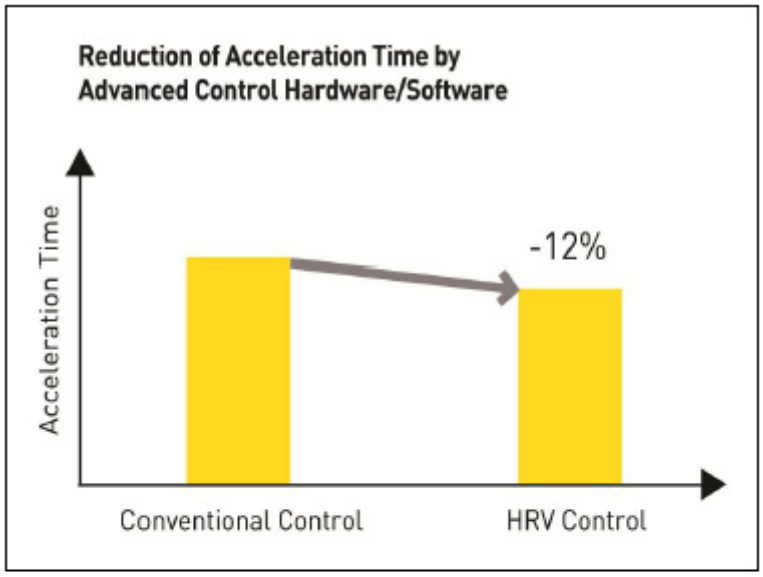


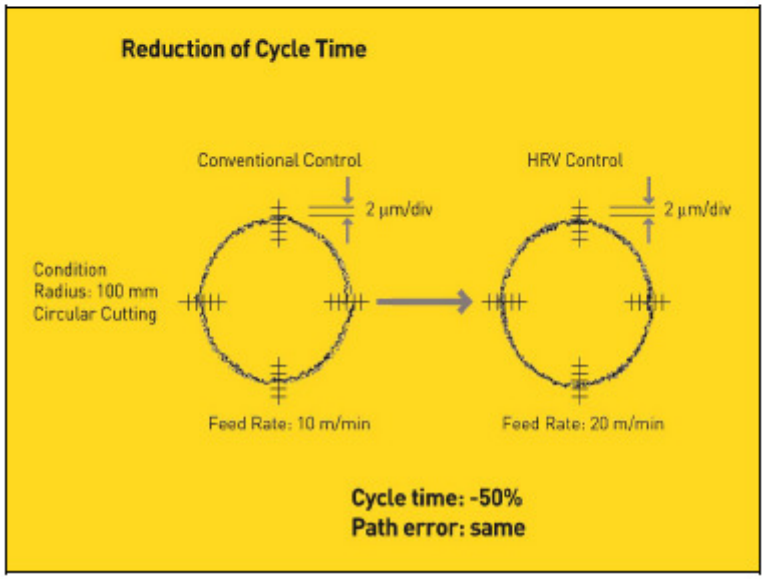
Acceleration Comparison



High response for optimized control

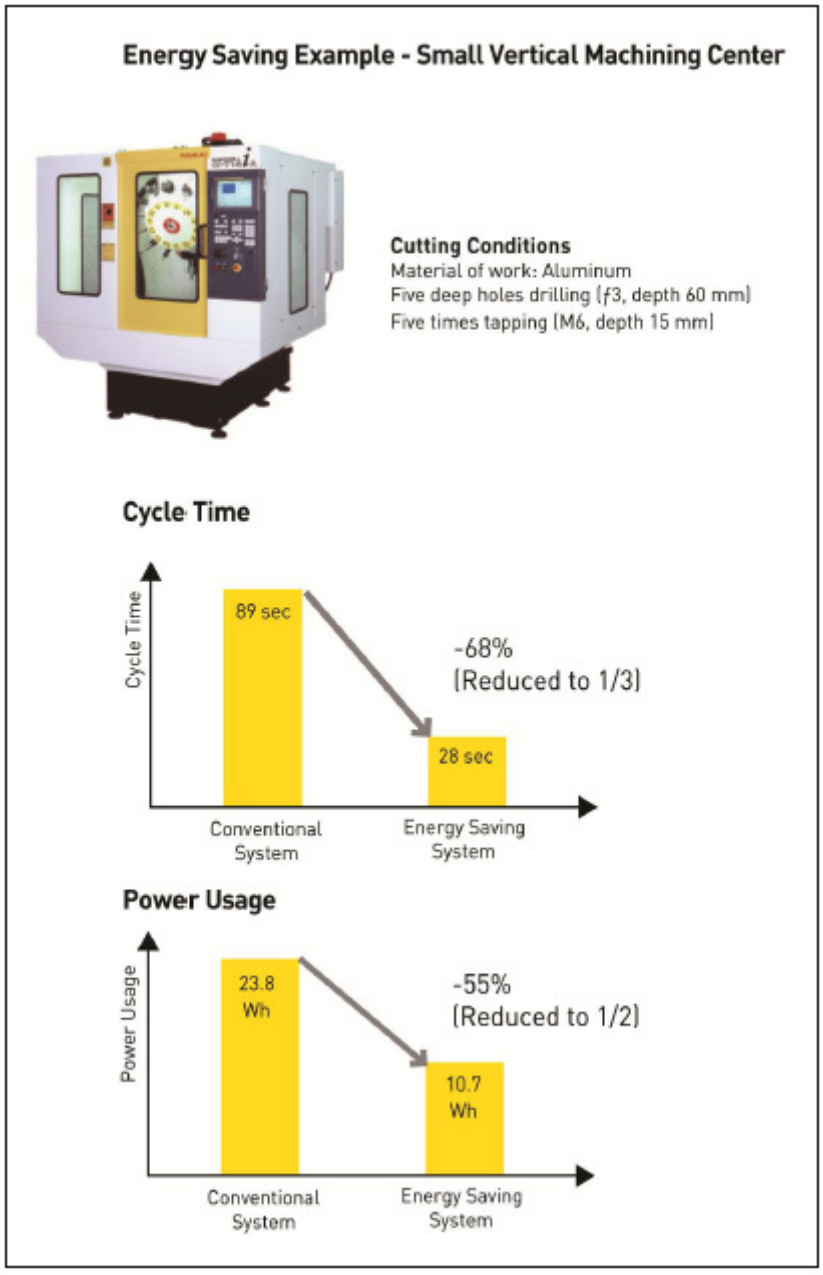
Mechanical changes within the motor design provide the potential for improved acceleration and increased speeds but creating a control unit that will capitalize on these improvements is critical. Pulse width modulated drives require advanced switching devices and precision software to efficiently control electric motors. Functions like HRV (High Response Vector), an advanced form of field-oriented control, closes the motor control loops at a very high rate. HRV also adjusts the commands based on the load and RPM of the motor. Quickly and accurately responding to deviation allows the control system to take full advantage of the motors and mechanical system. Acceleration and maximum speeds can be increased without sacrificing accuracy. The net result is higher productivity and a reduction in energy usage.





Electrical Energy Reduction, Putting It All Together

Significant electrical energy saving is best achieved by improvements in the direct and indirect components simultaneously. Improvements explained throughout this article will have impressive operational cost savings. The greatest impact will come from the selection of high efficiency, high performance motors with drive amplifiers that use power source regeneration. Reducing waste heat and inefficiencies within the power components contributes significantly to the direct component of energy savings. Reduction in the cycle time by increase speeds and acceleration lower the indirect component. Used together these improvements in efficiency can be dramatic.



Conclusion

Advancements in electric motor design and the associated drive system in modern automation equipment can be extremely energy efficient. Usually the most energy efficient machine will also have the highest performance but there is normally an upfront cost associated with the performance and efficiency. That added cost related with selecting energy efficient equipment may be easily returned as lowered energy costs, high performance and reliability. Too often inefficient machines are selected based on purchase price without concern for the lifecycle cost. As energy prices continue to increase the total lifecycle cost of inefficient machinery will come to the surface. It is time to look closely at equipment efficiency as part of the decision making process when purchasing automation equipment. So, choose your next CNC system wisely.

Article Sources:

o *US Department of Energy
o FANUC environmental report 2005
o FANUC test data

FANUC FA America
1800 Lakewood Boulevard
Hoffman Estates, IL 60192
Tel: 888-FANUC-US (888-326-8287)
Fax: (847) 898-5001
www.fanucfa.com