THE PROFIenergy PROFILE

Increasing the Energy Efficiency of Automation Systems using Smart Energy Management over PROFINET

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A WIN/WIN FOR ALL, INCLUDING THE PLANET!

1 Executive Summary

Automation users worldwide are driven to minimize energy consumption, to cut costs and comply with increasingly stringent 'green' obligations. Methods range from switching off equipment manually to installing semi-automated shut-down systems. These are crude, expensive or hard to manage.

What is needed is a standardized way to manage energy consuming devices over production networks, eliminating the need for external systems and delivering a solution that can be configured intelligently using existing automation equipment.

The PROFIenergy Profile enables control devices (e.g. PLCs) to send commands to Energy Consuming Units (ECU), to signal pauses such as lunch breaks, holidays, random line stoppages or even peak load conditions. On receipt of the PROFIenergy commands, software 'agents' in the ECU firmware initiate pre-defined 'sleep' modes for the duration of the pause.

PROFIenergy commands are usually be issued by the same controller as the automation process. However, a dedicated energy management controller can be used. PROFIenergy is applicable to single devices such as actuators and remote IO as well as complete sub-systems such as paint lines.

PROFIenergy enables the deployment of smart energy management strategies over PROFINET. Actual energy savings depend on how end users adapt PROFIenergy to their production environments.

Robot cells, lasers and drives (where up to 60% of energy can be consumed during production pauses) will be early beneficiaries, but as more intelligent ways evolve to use PROFIenergy the overall benefits for industry could be significant.

2 Introducing PROFIenergy

The idea for a standardized energy management strategy for automation sprang from the AIDA group of automotive manufacturers in Germany. AIDA companies - Audi, BMW, Mercedes, Porsche and VW – comprise a major part of the European automotive industry. Although acting competitively in the marketplace, they collaborate over areas of common interest, especially those related to manufacturing. For example, they agreed several years ago on PROFINET as their preferred next-generation industrial network, in order to eliminate the 'choices' that arose from earlier fieldbus experiences. By focusing on a single technology, they reasoned, life would be made easier and less costly for everyone.

Energy is one of the biggest operating costs in automotive manufacturing. It's also subject to other important issues - security of supply for example, and concerns about climate change.

Could there be a special Profile of PROFINET that would standardize an approach to energy saving? AIDA asked. Would PI, with its multi-vendor support and vast experience in developing automation standards based on networking technologies, be willing to help?

A PI Working Group was set up early in 2009. A specification has now been published (available to members at www.profibus.com). The consortium involved in its development is shown here – it's a a mix of vendors, OEMs and service suppliers.

First implementations of PROFIenergy are expected to appear during 2010.

The PROFIenergy Consortium

3 Energy Efficiency

Surprisingly, given intense publicity in recent years about security of supply, costs and 'green' responsibilities, energy management remains an inexact science. Beyond the basic thermal efficiencies which are relatively easy to take into account, many plants are still being designed and built without regard for short-term production pauses such as holidays, downtime and even overnight operations. Integrated energy management strategies are rarely employed, a situation that surely has to change.

Quantifying the total energy consumption of industry is not hard – it can be easily determined on the Web after a few clicks. It is usually measured in trillions of dollars, depending on which country or region is being considered.

The results of energy efficiency analyses can also be found by trawling the internet for projects that have attempted to understand where losses occur. One example determined that only 31% of purchased electrical energy was being used during production hours! In other words 69% of energy was consumed *NOT* making products! The 'productive spread' ranges down to 5% which may be manageable, although the implicit message is clear: energy wastage is probably occurring on a large scale throughout industry.

The potential benefits of increased energy efficiency are therefore massive. Different industries are obviously affected in different ways. Process industries that consume vast amounts of energy making or transforming products such as steel, glass and mining could be affected the most.

Some energy efficiency projects have been outstanding successes. One automotive line designed in conjunction with a major IT supplier managed to reduce energy costs by 70%, with an ROI of 18 months! Such examples are rare however, and most depend on bespoke solutions which are expensive and inflexible. The missing factor is a standardized way of managing energy consumption at the plant floor level, where most energy is used. Hence - PROFIenergy.

4 PROFIenergy in outline

PROFIenergy is an Application Profile of PROFINET. It relies on the collaboration of three automation elements: the controlling device in a PROFINET network (usually a PLC, but it could be a higher level supervisory system or even a dedicated energy management controller), the network itself (PROFINET), and one or more Energy Consuming Units, or ECUs (which could be a single device, a production cell or even a larger production unit). It's the interaction of these three that makes PROFIenergy so powerful.

The role of PROFINET is simple - it's to transmit standardized commands to each ECU under guidance from the controller, and to receive back status information and energy consumption data. It does this using the acyclic slots of the PROFINET communications protocol. PROFIenergy is fully integrated with existing automation processes and operates over the same PROFINET network.

During the idle period of a weekend for example, ECUs can often consume up to 60 percent of the total energy used during production (see below). With PROFIenergy, users can reduce this substantially by switching off unnecessary activity, thereby reducing energy demand.

Up to 60% of energy usage can occur during non-production periods.
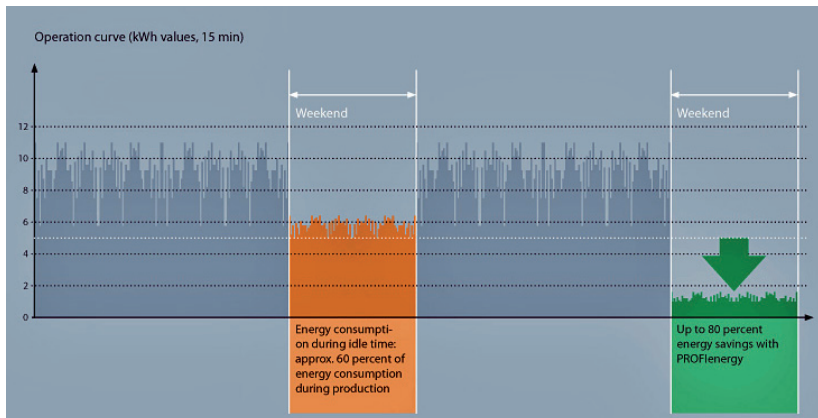
5 Why has this not been done before?

It has, but not with much success. Energy consumers in a production line are typically never switched off, usually because this requires additional hardware outside the machine (see below). In these kinds of system switching relies on external relays and everything has to be hard-wired. Such systems tend to be proprietary and therefore costly. Many users are naturally reluctant to commit the resources to do this.

Sometimes, semi-automated systems are used – again these tend to be proprietary and are generally hard-wired. The control task and the energy management procedures are combined and a complete 'switch-off' by disconnecting the power is the best that can be achieved.

Crude, expensive and hard-to-manage systems like these have never been popular and hence energy efficiency at this levels of automation has received less than adequate attention.

PROFIenergy, by contrast, requires no additional wiring or external hardware because signals are transmitted over the existing PROFINET cabling and all switching takes place inside an ECU.

PROFIenergy allows energy consumption to be managed dynamically, device by device. Above all, PROFIenergy delivers a common solution that vendors and users can support together, bringing all the familiar benefits of 'openness' as well as potentially huge cost benefits.
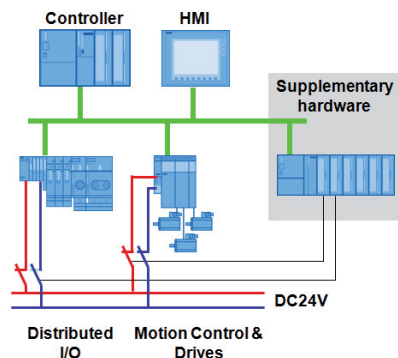
**Conventional energy management systems require external hardware and wiring**

6 How does PROFIenergy work?

With PROFIenergy, the switching mechanisms controlling the ON/OFF modes of equipment reside inside the ECUs themselves. These 'understand' the PROFIenergy commands issued by the controller. At appropriate times - determined during configuration or dynamically decided in accordance with production circumstances - the controller sends signals to the ECUs stating when production pauses will happen.

These pauses - or stops in production - may be routine, or they can occur in response to production conditions e.g. a breakdown. Each ECU then decides how a pause is to be handled using software 'agents' embedded in its firmware that react to the 'start pause' and 'end pause' signals from the controller.

Incorporating PROFIenergy's functionality in end devices means that equipment vendors themselves decide how to optimize the energy management of their own equipment. This recognizes that they probably understand better than anyone the right actions to take for particular combinations of equipment and pause times.

The approach gives complete freedom to the vendor and provides flexibility: for example, a drive may have to be run down to idle over a 30 second period, or perhaps a production cell requires that a conveyor be slowed down before a robot can be put into 'sleep' mode. If the duration of a pause is long enough perhaps the ECU can be completely disconnected ... but to be ready to re-start its conveyor must be re-started in advance. This kind of flexible timing strategy is depicted in the diagram right.
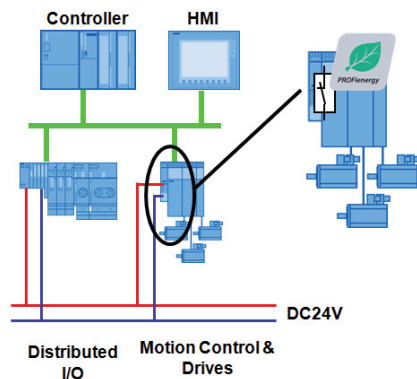

With PROFIenergy, ON/OFF control happens over the network

PROFIenergy's command system will usually be deployed in the same controller (e.g. a PLC) that is running the automation system. However, it could reside in a separate, dedicated, energy management controller. Multi-level 'sleep modes' are feasible.

As experience grows and PROFIenergy-enabled devices become more widely available, we can expect to see more sophisticated possibilities being put into practice. For example, PROFIenergy's ability to feedback energy consumption data to the controller means that a load-dependent machine control strategy could be implemented to help avoid peak demand penalties.

It is also possible for secondary processes to be paused during production when not needed. Even non-electrical power sources (e.g. steam and compressed air) could be managed better using PROFIenergy.
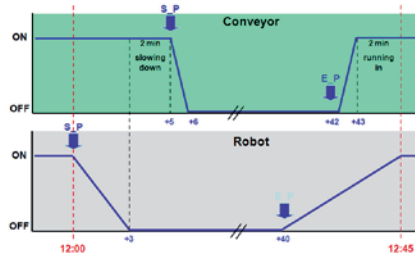
Power ON/OFF timings are pre-configured by the vendor to suit the equipment

7 The PROFIenergy Use Cases

PROFIenergy Use Cases (UC) have been defined in collaboration with end users. They serve as the basis for the PROFIenergy specification and can be summarized as follows:

Brief pauses (typically up to one hour) - These are pauses during the manufacturing process which make it possible to put ECUs either into a standby condition, or switch them off completely. In general, such pauses are planned - e.g. lunchtime breaks. Interruptions like these last from a few minutes to up to one hour. The PROFIenergy system selectively switches off those ECUs that will save energy during that time but that can also be powered up again and on time. Safety-related functions are retained and protected. When production restarts, the system activates the ECUs in a pre-defined switch-on sequence and checks that they all have started correctly. The system then restarts the production process. Whether and which ECUs are sent into 'sleep mode' has to be determined and configured by the user. For some devices it may not be reasonable - or even possible - to put them into standby or switch them off because it takes too long ... or perhaps it takes more energy than is saved.

Longer pauses (typically a range of hours or days) - This use case is similar to the first one, the difference being the duration of the pause. It lasts hours (e.g. overnight) or even days (e.g. weekends and holidays). Because the pause is longer, additional ECUs can be put into standby, or switched off completely, or the same ones can be put in a more energy saving state because more time is available. Nevertheless, the rules for not switching off an ECU might still be valid, e.g. functional safety has to be treated very carefully! A general benefit is that the longer the pause lasts the more energy can be saved. An ECU could also have different levels of energy saving, especially complex ones like tooling machines or welding robots. PROFIenergy allows for any number of intermediate energy-saving modes to be triggered during the pause.

Unscheduled pauses (typically caused by equipment failures) – This Use Case is also similar to the ones above, the difference being that the user doesn't know when the interrupt will occur, nor how long it will last. Initially, the ECU is put into a 'stop'

condition to reduce energy consumption as if for a brief pause. If it turns out that the repair work will take a long time, the possibility exists to place the equipment into an even more energy-saving state for the duration of the pause.

Measuring and visualization of the load – This covers the acquisition of measurement data from the ECU, either directly or implicitly, and is needed because knowledge of when, where and how much energy is required enables more effective energy management. Possibilities include high energy machines being substituted with lower energy alternatives. Moreover, the energy consumption of a machine can be visualized and archived on an HMI. Semi-automatic responses then become possible because the information can be used to control energy consumption manually, leading to more flexible reactions especially during unplanned pauses.

The power consumption of some devices may already be available to the network – for example if dedicated power monitoring devices are installed. Further, many devices employ power monitoring techniques during normal operation - for example, motor starters and frequency converters. These devices measure parameters such as power, reactive power, current and power factor angle and, although this information is not comprehensive, it may be sufficient to visualize energy consumption. Peak load demand management also becomes possible with PROFIenergy.

The first version of the PROFIenergy Profile focuses on electrical energy. However, other energy resources are consumed in manufacturing lines by systems such as gas, steam, compressed air and water. The consumption of energy in these types of system may be added to a future PROFIenergy specification.

8 Implementation

PROFIenergy requires only a simple set of commands to be used by the controls engineer and, at the 'entry' level - where most PROFIenergy systems are likely to fit in the short term - there is little additional work to carry out. This may change over time as more sophisticated strategies are introduced.

Device and system manufacturers will embed software 'agents' in their equipment to manage the pause procedures, so detailed knowledge of these is not necessary for the user. Only the 'start pause' and 'end pause' commands need to be set.

To take into account the need for upgradability and compatibility, PROFIenergy commands have been mapped onto existing PROFINET acyclic services. These do not occupy additional addresses in the process image. So, the volume of user data is not altered and the new PROFIenergy commands can be used in existing program libraries without repercussion. Likewise, device manufacturers can use a firmware update to expand their components to include new PROFIenergy functionality.

The separation of energy management and control functions means both parts of the control program can be tested and commissioned independently. Structured programming greatly simplifies the maintenance of the user program in the long term.

A future version of the PROFIenergy Profile may add functionality to the specification – for example to aid engineering or to manage the consumption of non-electrical forms of energy. It may even become possible at a later stage to simulate the energy consumption of a plant and calculate the best PROFIenergy strategies for a particular set of equipment.

PROFIenergy guarantees a uniform interface for energy management and is an open technology, with all the benefits that brings in multi-vendor situations. The user is free to choose devices from different manufacturers to best suit his application or budgets.

9 PROFIenergy Benefits

PROFIenergy savings arise as follows:

• **During Installation**: Conventional energy savings systems - when used - are hard wired, unsophisticated and proprietary. Networking eliminates all these disadvantages since PROFIenergy comes 'built in' and therefore involves little installation effort. This could be particularly significant in high labor cost countries.

• **During Operation**: Savings depend on the strategies used but in general the biggest benefits will come from heavier power demand devices and sub-systems. However, smaller devices with relatively low power consumption may also generate substantial savings where large numbers are used (e.g. Remote IO modules).

• **Asset Protection**: Switching functions are integrated in devices. Instead of clumsy 'ON/OFF' manual switching, equipment will be powered up and down intelligently, resulting in longer life and fewer breakdowns.

• **ROI**: As cost savings are potentially significant, rapid ROI can be anticipated. Any higher up-front costs will easily be offset.

• **Engineering**: Short and long pauses are managed by the interaction of IO controller (PLC), PROFINET, and the software in the Energy Consuming Unit (ECU). As experience grows, OEMs and device vendors will learn how to use this interaction more and more intelligently.

• **Peak Load Management**: Measurements of energy consumption from the ECU can be fed back to the IO controller (PLC) or supervisory system to allow consumption to be reduced and peak demands limited.

• **Competition**: A standardized, 'open', solution can be supported widely by vendors, OEMs and end users. Interoperability and choice lead to competition, with performance and functionality rising as costs fall.

• **Regulatory pressures**: Cutting power consumption reduces carbon footprints, and helps support 'green' strategies to meet growing regulatory requirements.