CIP Energy Profiles

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Abstract:

The ODVA Energy Applications Special Interest Group (SIG) has invested significant work to define an Energy Management Object. This object complements the previously defined energy awareness and power management objects. The Common Industrial Protocol (CIP™) energy objects define standard attributes and services for measuring power and energy as well as reducing energy usage, during idle time and during production. The objects also support optional attributes and services that allow vendors to implement these objects in various ways. This variety may present challenges to system designers and end users when selecting and deploying devices with CIP energy objects in actual operation.

In the CIP specification, device profiles are defined. The profiles benefit customers because different devices from different vendors with the same device profile are interchangeable from a CIP perspective. A similar concept could be deployed from an energy perspective. An energy profile would not replace, but would complement, a device profile, since it should be possible for a device to have both a device and an energy profile.

This paper will introduce the concept and benefits of an energy profile. A brief introduction to the CIP Energy™ Objects will first be presented. Based on these objects, several profiles will be explored (e.g. power meter, drive, PLC, etc.). For each of these profiles, the energy objects that are present, as well as the optional services and attributes that should be present are defined. In addition, both device and client behaviors are considered, as well as application use cases.

Keywords:

Energy Profile
Energy Awareness
Power Management
Energy Management

Definition of Terms

CIP – the Common Industrial Protocol, an industrial automation communications protocol suite supported by ODVA

Device Profile – a specification of a device's object model, configuration and behavior that promotes consistency and interoperability among devices of the same type

Aggregation – a data representation of the totalized energy or power consumed or generated by a collection of devices

Child – a member of a collection of devices being represented by an aggregation object

CIP Energy Objects

Energy is an indispensible component of industrial production but has been ineffectively managed as a production resource. Acquiring energy information detailed enough for action has been difficult and costly. Automation to control energy usage and related costs has likewise been costly, characterized by one-of-a-kind designs, hours of custom engineering effort and difficulty in cost justification. ODVA's Optimization of Energy Usage (OEU™) comprises a three-tiered approach to increasing the availability of less costly, more granular energy information; and standardizes approaches to the automation of power and energy management. The three phases of OEU are:

- Awareness of energy usage;
- Consuming energy more efficiently; and
- Procuring energy at the lowest cost

The ODVA Energy Applications SIG has published and is working on new specifications for a family of independent but related CIP Energy Objects to support the OEU strategy and support the addition of energy capabilities to a variety of CIP devices.

Awareness of Energy Usage

Three related data object specifications comprise the energy awareness suite of ODVA energy capabilities.

- The **Base Energy Object** lets devices from simple to complex report their energy usage in a standardized way, in units of kilowatt-hours (kWh). This native electrical energy unit was selected because many ODVA members are electrical device vendors. The Global Reporting Institute (GRI) specifies units of gigajoules (GJ) for energy reporting; however values in kWh may be easily converted to values in GJ by multiplying by 0.0036. This object also reports accuracy and information on how the data is generated. The Base Energy Object can also be used to report the aggregated usage of a collection of devices, and can act as a proxy, reporting energy usage for devices that cannot do so themselves, or can but are not CIP devices.

- The **Electrical Energy Object** reports a variety of electrical measurements, including voltages, currents, complex power and energy, power factor, frequency, etc., similar to the types of parameters you would find in a high-end meter or power monitor.

- The **Non-Electrical Energy Object** reports usage of energy resources such as natural gas, steam, fuel oil, hot water and chilled water, each in their native energy units (e.g. therms, pounds, gallons, Btus, joules, etc.).

Some devices may report very accurate energy data, but high accuracy is not really needed at the device level. There will usually be revenue-accurate meters upstream in the energy distribution network. The energy awareness objects are intended to cost-effectively fill in missing pieces of the energy usage picture where today little or no information exists. This more complete energy picture provides valuable information on the energy behavior of a machine, zone, line or area, allowing users to make decisions that result in reduced energy usage and cost.

An Electrical Energy or Non-Electrical Energy Object instance is optionally associated with an instance of the Base Energy Object. These subordinate objects do not provide aggregation; however, a Base Energy Object instance can report the aggregated usage of a collection of similar Non-Electrical Energy Object instances ("similar" means the instances report usage of the same energy resource in the same units). It then reports the aggregated usage in kWh in its own instance attributes, and in the native non-electrical energy units in an associated instance of the Non-Electrical Energy Object. That way, the user can get a single view of all of the energy being used in multiple devices and subsystems in the base units (kWh) while also being able to monitor the non-electrical loads in the units that make sense for those types of devices and subsystems.

Together, this collection of energy objects provides standardized ways to obtain detailed energy usage information in an industrial setting at very low cost. This can help users apply a more direct relationship between parts and the energy utilized to manufacture them.

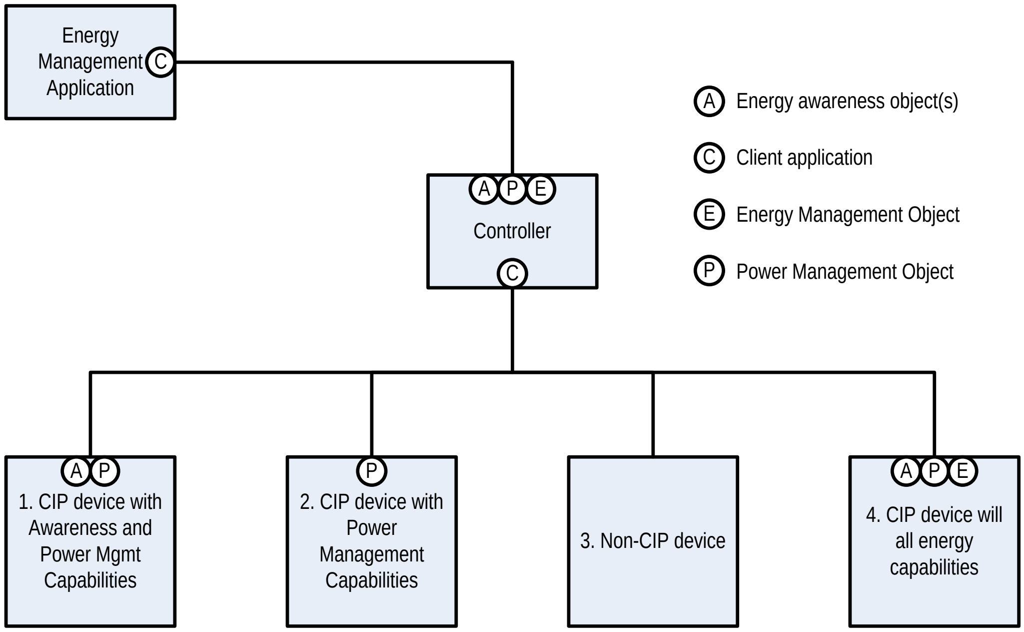
Consuming Energy More Efficiently

The Power Management Object provides a simple, standardized interface for commanding devices, machines, work cells and production lines into low-power modes at lunch time, shift change, weekends, when a bottle-neck or breakdown occurs, or during other significant idle periods. A controller or software application requests a pause expected to last for a specified time. In response, the device reduces the power it uses by going to a predefined pause mode, and letting the application know how much notice to give so the device will be ready when needed. Based on the requested pause time, a device selects a pause mode that saves the most energy possible for the duration and condition of the device. The lowest power level is the "sleeping" mode, where it effectively shuts down except for just enough communications hardware capability to listen for a wake-up call.

Where the Power Management Object saves energy during idle periods, the Energy Management Object helps to save energy and avoid demand peaks while production continues at a lower rate of energy consumption. The Energy Management Object uses predefined curtailment levels to reduce power. Curtailment levels are similar in function to pause modes, except the energy managing application requests a desired power level instead of the duration of a pause.

Both the Power Management and Energy Management objects act as servers to an energy management client application. The client, which may in turn be a server itself to another higher level energy management client application, needs to maintain awareness of the big-picture operational environment to manage the energy behavior of its owned devices using services defined in the object specifications.

A real-world system could combine devices and applications with many different capabilities. The diagram below illustrates an example.



In this somewhat complex example, an energy management application serves as a client to a controller, which supports the CIP awareness, power management and energy management capabilities as a server to the energy management application. The controller in turn acts as a client to the devices below it in the architecture. The controller could also act as aggregator, reporting total power and energy to the energy management application; as a proxy to devices that lack CIP awareness capabilities, and may need to control devices without CIP power or energy management capabilities directly, by manipulating their inputs and outputs.

This example also demonstrates a need for a clear method for identifying energy capabilities of CIP devices. The next section presents a possible method for classifying devices as to their energy capabilities.

Energy Profiles

In the CIP specifications, Device Profiles are used to “provide interoperability and promote interchangeability[1]” among similar devices from different suppliers. A device profile defines required and optional objects, behaviors, format of I/O data, configuration parameters, etc. A device profile is associated on a one-to-one basis with a particular device type.

The CIP Energy Object family has been developed to allow many types of devices to become “energy capable” in a standardized way. Devices such as AC Drives, circuit breakers, motor starters, motor overloads, soft starters, servo drives, programmable controllers and other devices can be made more valuable by adding energy capabilities. Energy is a horizontal capability that cuts across many, many device types, so creating an exclusive “energy” device type just wouldn’t make sense.

A particular device may combine energy awareness and energy efficiency capabilities by supporting instances of the Base Energy Object, an Electrical or Non-Electrical Energy Object, and the Power Management and/or Energy Management Objects. An energy profile is a way to easily identify energy capabilities that are implemented in a device.

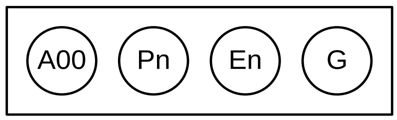
[1] Chapter 6, Device Profiles

An energy profile is a new concept that promotes similar interoperability and predictability of behavior but is not exclusive to a device type. Like the device type, an energy profile defines energy and power related objects, services and behaviors which are implemented in an energy-capable device. An energy profile could also help meet application needs by requiring the implementation of certain optional attributes or services. An energy profile, in addition, could form the basis for conformance testing of energy-capable devices and provide a medium for documenting informative application considerations (e.g. "Tips and Tricks" or usage guides).

In addition the Identity Object could be augmented to include an energy profile attribute, similar to the Device Type attribute that references a Device Profile.

CIP Energy Identification

The energy profiles presented in this white paper are offered as a possible basis for "energy identification" of CIP energy-capable devices. An idea for identification could be an image of an old-fashioned kilowatt-hour meter:



In this concept, the four dials would indicate, left to right, Awareness, Power Management, Energy Management, and Smart Grid support (Smart Grid support is a future Optimization of Energy Usage project).

The subscripts could have the following meanings:

- A – Awareness
    - First subscript character
        - 0 = Generic
        - 1 = Electrical
        - 2 = Non-Electrical
    - Second subscript character
        - 0 = Energy Measured
        - 1 = Energy Derived
        - 2 = Energy Proxy
        - 3 = Energy Aggregated
        - 4 = Energy Rate Fixed
        - 5 = Non-Electrical Aggregated

- P – Power Management
    - n = No Sleeping Mode support
    - s = Sleeping Mode Support

- E – Energy Management
    - n = Curtailment Levels are modifiable
    - p = Curtailment Levels are protected from modification

- G – Smart Grid support (future)

This concept of "energy identification" for CIP energy-capable devices would provide general information on a device's energy capabilities. Further information could be provided in the Declaration of Conformity or vendor's documentation for each device.

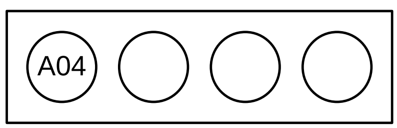
What does "Energy Capable" really mean?

"Energy Capable" is a broad term that indicates that a device supports some implementation of one or more energy related CIP objects. Within that broad classification there are myriad details that further define what capabilities are supported, what attributes a device supports, and how it would be expected to behave. Energy profiles could be used to help classify devices according to their detailed energy capabilities. A number of examples of energy capable devices are listed here, ordered roughly from simple to complex.

- **Simple energy aware devices** – An example of this type of device is a power supply with communications but without the ability to measure power and energy. The device reports a value of power when it is turned on (e.g. 5 kW). When powered off, the device no longer communicates, so its power can be assumed to be zero. The energy object instance in this type of device may be implemented only in the device's communication firmware rather than in its base firmware. This type of device reports only power values, which its client needs to integrate over time to obtain energy usage data. This type of device could be characterized as follows:

Object / Capability	**Supported?**	**Comments**
Base Energy Object	Yes	
Capabilities – Energy Fixed	Yes	
Energy Odometers	No	Reports one or more nominal or user-defined power values that remain steady when in an operating state and change infrequently relative to the rate at which the data is read from the instance.
Energy Transfer Rate	Yes	Power in kW; required since odometer is not implemented.
Energy Accuracy = undefined	Yes	Power value is estimated, not measured. This type of device should not be included in a collection to be aggregated.

The CIP energy identifier for this example (using the model described above) would be:

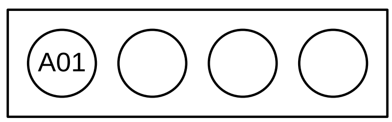


- **Power and energy measurement devices** – Devices in this classification are able to measure voltage and current, calculate their power value, and integrate power over time into energy. Some devices in this category can be very accurate, but it's not a necessity. Examples of this category of devices may include power monitors, AC drives and soft-start motor controllers. These devices could be characterized as follows:

Object / Capability	**Supported?**	**Comments**
Base Energy Object	Yes	
Capabilities – Energy Measured	Yes	
Energy Odometers	Yes	Required for devices capable of measuring energy
Energy Transfer Rate	Optional	Power in kW; optional since the odometer is implemented.
Accuracy	Yes	May be very accurate, even revenue grade (power monitor). AC drives and similar devices may be less accurate.
Electrical Energy Object	Optional	(Implemented in this example) Provides electrical values in addition to power and energy, e.g. volts, amps, frequency, etc. Support of the Electrical Energy Object is desirable in any device that supports the Energy Measured capability.

- **Devices that derive energy from other data –** These devices use available data to provide an estimate of energy usage. The Energy Derived capability offers device vendors the ability to creatively apply energy capabilities to existing devices with minimal changes. An example is a motor overload relay that measures motor current in order to protect the motor. Such a device can calculate energy usage using the measured current, an estimated motor voltage, and power factor obtained from a representation of the motor characteristic curve. The table below characterizes this example.

Object / Capability	**Supported?**	**Comments**
Base Energy Object	Yes	
Capabilities – Energy Derived	Yes	
Energy Odometers	Yes	Required for devices capable of deriving energy
Energy Transfer Rate	Optional	Power in kW; optional since the odometer is implemented.
Accuracy - estimated	Yes	Determined empirically; may be in the range of 5 to 15%
Electrical Energy Object	Optional	Provide electrical values in addition to power and energy, e.g. volts, amps, frequency, etc.

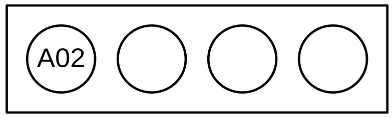


- **Proxy devices that represent non-CIP devices –** A proxy device will typically be a fairly capable CIP device such as a programmable controller[2] or MODBUS translator, with the ability to monitor the status of inputs and outputs and compute power and energy associated with those signals. Many examples of proxy applications can be imagined. This example uses a programmable controller with a discrete output that controls a 100 HP across-the-line starter and analog inputs that reflects the pressure and flow generated by the controlled motor and pump (the proxied device). The controller computes power and energy based on the state of the inputs and a stored model of the pump that relates pressure and flow to energy usage. This example is characterized in the following table.

Object / Capability	**Supported?**	**Comments**
Base Energy Object	Yes	
Capabilities – Energy Proxy	Yes	
Energy Odometers	Yes	Required for proxy devices
Energy Transfer Rate	Optional	Power in kW; optional since odometer is implemented.
Accuracy	Yes	Estimated accuracy is determined empirically; may be in the range of 10 to 25%
Electrical Energy Object	Optional	It is unlikely that a proxy device would have enough awareness of its proxied device to populate data in an Electrical Energy Object
Non-Electrical Energy Object	Optional	Not used in this example, however, could be useful

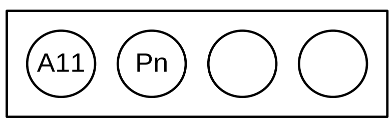
[2] Application of energy profiles to programmable controllers or other highly configurable devices could present special challenges as the implementation of energy capabilities may depend significantly upon user configuration and/or programming.

Object / Capability	Supported?	Comments
		when the proxied device uses non-electrical energy.



- **Devices that provide energy data and can be power managed** - Devices that combine energy capabilities provide additional value to the machine builder and end user. The Power Management Object assists in reducing energy usage during idle periods, and the device's energy awareness capabilities help confirm the reduction. As an example, let's consider an AC drive, characterized as follows:

Object / Capability	Supported?	Comments
Base Energy Object	Yes	
Capabilities – Energy Measured	Yes	
Energy Odometers	Yes	Required
Energy Transfer Rate	Optional	Power in kW; optional since the odometer is implemented.
Accuracy - nominal	Yes	Calculated; may be in the range of 5 to 15%
Electrical Energy Object	Optional	(Implemented in this example)
Power Management Object	Yes	
Pause Modes	Yes	2 modes likely: • not paused (controlled by application) • paused (drive stopped but still powered up)
Sleeping State	Optional	Additional hardware likely needed • Ethernet PHY • Line contactor

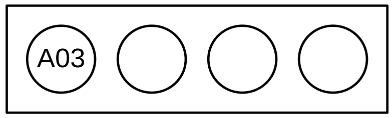


- **Devices that aggregate energy usage of a collection of devices** – An energy aggregator presents a consolidated value of energy usage of a collection of devices. An electric meter installed at the incoming power terminals of a machine naturally aggregates the energy used by the machine components. Likewise, a Base Energy Object instance at the machine level can provide similar aggregated usage data without the cost of a meter. The Base Energy Object goes into some detail on aggregation and its application considerations. The important functions of an aggregator are:
  - Periodically monitor the values of energy odometers in the collection of devices and combines them into an independent aggregated energy odometer
  - Correct for discrepancies in the data obtained from the "child" devices in the collection, for example, a rollover or reset of a child device's energy odometer.
  - Calculate the nominal accuracy of the aggregated energy usage (this is made more difficult if child devices report "undefined" accuracy)

  An energy aggregator may be characterized as follows:

Object / Capability	Supported?	Comments
Base Energy Object	Yes	
Capabilities – Energy Aggregated	Yes	

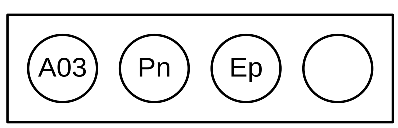
Object / Capability	Supported?	Comments
Energy Odometers	Yes	Required
Energy Transfer Rate	Optional	Power in kW; optional since the odometer is implemented.
Accuracy - nominal	Yes	Calculated; based on accuracy of child devices and their contribution to the total
Electrical Energy Object	Unlikely	Electrical values other than energy and power don't lend themselves to aggregation.



- **Devices that allow energy management of a machine or line** – The final example combines the energy aggregator with an energy management proxy capability. Imagine an OEM machine using a programmable controller where the controller serves as an energy aggregator, reporting the consolidated energy usage of the machine in a Base Energy Object. The machine could comprise a collection of CIP and non-CIP devices and be managed by a controller which hosts an instance of the Energy Management Object that permits an energy manager application to command the machine to curtailment levels and thereby reduce energy usage.

  The machine builder, during machine design or commissioning, defines curtailment levels and saves them once the machine is in operation by setting a capability attribute value. The machine controller could also implement the Power Management Object to further reduce energy consumed during idle periods. The aggregated energy value provided by the Base Energy Object can be utilized to verify the energy performance of a machine. This example is characterized in the table below.

Object / Capability	Supported?	Comments
Base Energy Object	Yes	
Capabilities – Energy Aggregated	Yes	
Energy Odometers	Yes	Required
Energy Transfer Rate	Optional	Power in kW; optional since the odometer is implemented.
Accuracy - nominal	Yes	Calculated; based on accuracy of child devices and their contribution to the total
Energy Management Object	Yes	
Capabilities = Protected	Yes	Protected from modification
Curtailment Levels	Yes	As defined by the machine builder
Power Up Curtailment Level	Optional	Uncurtailed or Last Level as defined by the machine builder
Power Management Object	Optional	As defined by the machine builder



The examples described above are not meant to be a comprehensive list of the possibilities. They are intended to provoke thought and form the basis for further discussion.

Declaration of Conformity (DoC)

If energy profiles are adopted as a way to coordinate and describe the energy capabilities of devices, they could also be used effectively to categorize energy capabilities in a device's DoC. The DoC could include the energy identification symbol and add a section that would provide additional detail on the energy related objects supported by a device or family of devices.

Conclusions

The Energy SIG is promoting and working toward a concept of Energy Profiles as a method to coordinate the application of various energy-related CIP objects. Energy Profiles would provide a simple and effective means to communicate a device's energy capabilities for vendors, machine builders, solution providers and end users. Energy Profiles could reduce the effort needed to ensure that devices deployed in an application possess the needed capabilities. Energy Profiles would promote interoperability and interchangeability among vendors, and make it easier to experience the benefits of more detailed energy information and more cost-effective energy management.

References:

1. Base Energy Object, CIP Specification, Volume 1, Section 5-51
2. Electrical Energy Object, CIP Specification, Volume 1, Section 5-52
3. Non-electrical Energy Object, CIP Specification, Volume 1, Section 5-53
4. Power Management Object, CIP Specification, Volume 1, Section 5-54
5. Power Management Object, EtherNet/IP™ Specification, Volume 2, Section 5-10