Factory Energy Management System Using Production Information

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As a result of the Great East Japan Earthquake in March 2011, electric power supply in Japan faced a critical situation; in particular, factories that consume a large amount of electric power were seriously affected. Meanwhile, in China and other emerging countries, where the economic growth rate is high and automation of manufacturing factories is progressing, further energy saving is a key issue for economic growth and global environmental protection.

“e&eco-F@ctory,” Mitsubishi Electric’s factory automation (FA) energy solution, is aimed at reducing the total cost of ownership (TCO) and establishing a low-carbon society by integrating IT systems into production equipment to achieve higher productivity and energy saving in factories around the world.

1. Introduction

Manufacturing factories, as high-volume energy users, are required to promote further energy saving, and thus focus is placed on the Factory Energy Management System (FEMS), which manages the energy throughout the factory. The energy usage areas in the factory are largely divided into two categories: the “production system” where the actual production takes place using production equipment, and the “utility system” that functions as a part of the factory’s infrastructure. Mitsubishi Electric has been promoting the “e&eco-F@ctory” FA energy solution as a subset of FEMS that contributes to energy saving in the production system.

In the production system, productivity improvement and energy saving are closely related to each other. Improvement of the equipment utilization rate reduces unnecessary energy derived from equipment waiting time and downtime, while reducing the takt time also saves energy by decreasing the equipment operation time while keeping the same production quantity. In addition, quality (yield) improvement helps reduce unnecessary energy consumed for producing defective products.

This paper describes e&eco-F@ctory, which achieves energy saving by interrelating and managing the production information and the energy information to identify wasted energy in the production system.

2. FA Energy Solution “e&eco-F@ctory”

2.1 Total FA solution e-F@ctory

“e-F@ctory” is Mitsubishi Electric’s total FA solution for visualizing production by linking the shop floor and the information system, and for reducing TCO by driving the Plan-Do-Check-Action (PDCA) cycle. The concept of e&eco-F@ctory was created by adding energy as an additional element to the e-F@ctory solution.

The concept of e-F@ctory is depicted in Fig. 1, where the PLC that acts as the brain to control the
operating sequence of production equipment, plus various devices, sensors and other FA products are linked together via the FA network, and through which various kinds of production information are collected.

The MES (Manufacturing Execution System) interface, one of the PLC modules for directly linking the PLC to the database, connects the production equipment directly to the information systems without any communication gateway such as a personal computer. By using the MES interface, interconnection between the shop floor and the information systems is easily established at low cost.

2.2 Overview of e&eco-F@ctory

To survive global competition, manufacturers must improve not only productivity but also energy efficiency in order to reduce production costs. Meanwhile, in emerging countries with high economic growth rates, automation of manufacturing processes is making rapid progress accompanied by increasing use of electric power, although sufficient power supply is not secured.

With e-F@ctory, productivity is improved by using network technology and information systems. In addition, energy efficiency and productivity are achieved at the same time by using measuring technology developed in the field of electric power receiving and distribution, which is one area of Mitsubishi Electric’s power distribution control equipment business.

With e&eco-F@ctory, energy saving is achieved in four steps: “measurement,” “visualization,” “reduction” and “management” of energy.

An important factor of energy “measurement” is the collection of energy data in connection with production information such as quantity, not simply gathering energy use data from the shop floor. On the shop floor, the production information is stored in the PLC, and thus by providing the energy data to the PLC, it is possible to measure the energy that is interrelated with the production conditions and the operating status of the equipment. Therefore, Mitsubishi Electric offers an energy measuring module compatible with the “MELSEC-Q Series” PLC (Fig. 2).

In the “visualization” step, the energy and production information collected in the “measurement” step and provided to the PLC are analyzed using IT technology, and then that information is “visualized” in various ways such as by part, by product, and by equipment. The MES interface supports the “visualization” step by transmitting the energy and production information to the information systems.

For the successful “reduction” of energy, it is necessary to introduce energy-saving equipment with high energy efficiency. One example is to optimize the energy consumption of the facility and equipment by using inverters, motors and other drivers with high efficiency.

In the “management” step, which pursues improvement by interrelating energy information and production information, it is important to monitor the specific consumption and energy used by the facility and equipment. Specific consumption refers to the amount of energy consumed to produce one unit of a product. The e&eco-F@ctory provides various types of management solutions to improve productivity and energy efficiency by smoothly driving the PDCA cycle for better energy efficiency.

Figure 3 is an example of visualization, where the specific consumption is displayed by process, showing that the specific consumption represented by the line graph worsens in process (5) in association with the change in product model. This example is interesting in terms of energy consumption. By overlaying the cycle time represented by the bar graph, it can be clearly seen that the cycle time increased in process (5), which disturbs the balance in the production line as a whole.

![Fig. 2 Energy measurement by power measuring module](image)

![Fig. 3 Visualization using specific consumption by production process](image)
In this case, by improving the equipment in process (5) to reduce the cycle time, the productivity of the whole production line was increased and energy consumption as a whole was reduced.

3. Examples of System Configuration with e&eco-F@ctory

This section describes examples of the system configuration with e&eco-F@ctory, for three of its four steps, namely: “measurement,” “management” and “visualization.”

3.1 Visualization system for specific consumption

“EcoWebServer III” is an embedded data acquisition server that visualizes energy on a Web browser using its Web server function. The main functions of “EcoWebServer III” are as follows:

1. Measurement data acquisition (current, voltage, power, energy, leak current, etc.) from the CC-Link compatible measuring instruments (CC-Link is the global standard FA network “Control & Communication Link”).

2. In addition to the measurement data from CC-Link instruments, production information is collected from the PLC and accumulated in the built-in Compact Flash memory.

3. The embedded Web server function enables the status of energy use and specific consumption to be browsed via a local area network (LAN).

4. Without constructing a genuine EMS (energy management system) based on the server environment, a setting-only programless system can be quickly constructed (Fig. 4).

3.2 Visualization system interconnected with various production information

For simultaneous achievement of the goals of productivity improvement and energy saving, it is necessary to identify the improvement points for production and energy use. For this purpose, it is necessary to interrelate and manage various information about the production and energy. As an example, by managing the energy consumption in response to the operating condition of each production equipment (operating, standby, or breakdown), wasted energy during standby and breakdown can be found, and the time spent waiting for parts and for set-up change resulting in standby time can be reduced. This type of management can be achieved by linking the MES that manages the production information and the EMS that manages the energy information.

Figure 5 shows an example of the system configuration using Mitsubishi FA modules. The production information as well as the energy information acquired by the energy measuring module is transmitted via the MES interface from each equipment to the MES and EMS. In addition, the energy information for the whole line is collected from the multimeters, MDU breakers, etc., in the power receiving and distribution equipment and on the panel board, and then transmitted to the EMS via the MES interface.

4. Examples of e&eco-F@ctory Introduced in Mitsubishi Electric Factories

As an example of the “measurement,” “management” and “visualization” steps described in Section 3, this section presents the breaker production line at the Fukuyama Works, Mitsubishi Electric’s production base for electric power distribution control equipment.

At the Fukuyama Works, management of specific consumption has long been performed for each production line. Through small group activities, it was possible to identify the factors that may deteriorate the specific consumption and determine their countermeasures. However, since the specific consumption management had been performed on a line-by-line basis, detailed information about the production and energy were separate from each other, and so significant time and manpower were required to analyze the deterioration factors of the specific consumption. It was also difficult to pinpoint the bottleneck equipment in the line. Consequently, as shown in Fig. 6, the specific consumption management system was introduced in each equipment on the line. As a result, the bottleneck process was immediately identified, and by examining the production and quality information stored in the PLCs, effective factor analysis was performed and countermeasures against the deteriorated specific consumption were implemented.

The features of this system are as follows:

1. Energy measurement for each production equipment
The energy measuring module QE81WH, which is ideal for measuring equipment (small control panel), is installed in each production equipment. The energy is measured equipment-by-equipment and monitored by an upper-level database server.

(2) Input of production and quality information

The information stored in the PLC of each equipment, namely: production information (production quantity) and quality information (frequency, duration, type of error, etc., of short-term breakdown), is provided to the upper-level database server via the MES interface module. This enables detailed management of the specific consumption and effective factor analysis.

(3) Visualization at upper-level database server

On the conventional display screen for the specific consumption management, the specific consumption was calculated from the energy and production quantity...
for the whole line and their trends were displayed in chronological order. In this new system, the specific consumption per day per equipment is displayed for all equipment on one screen (Fig. 7).

2. Analysis of specific consumption

On the specific consumption analysis screen, detailed graphs of the specific consumption, and the frequency and duration of short-term breakdown are displayed in chronological order (Fig. 8). By displaying this information on one screen, it is possible to grasp the correlation between the deterioration of specific consumption and the short-term breakdown.

3. Analysis of short-term breakdown

The short-term breakdown analysis screen displays the breakdown count per day per equipment and the details (error description, occurrence time, time for equipment restoration, etc.). This information enables effective analysis and implementation of corrective measures for improvement of the equipment (Fig. 9).

5. Conclusion

This paper described application examples of “e&eco-F@ctory,” the FA energy solution, which focuses on reducing energy in production systems, one of the FEMS’s target areas for reducing the total energy in factories. While this system has been introduced in many factories around the world, the examples presented here were implemented at the Nagoya Works and Fukuyama Works, Mitsubishi Electric’s model factories.

We will roll out this solution globally, centering on Asian countries, especially in China, by converting Mitsubishi Electric’s own factories located in Dalian and Changshu to model factories.

To enhance this solution, we will examine the strategy for general energy reduction throughout the factory and also focus on the “utility system,” as well as restriction of peak power including energy generation and energy storage.