Abstract: - A factory consumes a lot of electric power. Especially, 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. This paper proposes the Factory Energy Management System (FEMS) based on production information. The FEMS 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 [1]. 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 [2].

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 [3].

This paper describes the FEMS based on production information, which achieves energy saving by interrelating and managing the production information and the energy information to identify wasted energy in the production system.

2 Overview of FEMS based on Production Information
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 the FEMS based on production information, productivity is improved by using network technology and information systems. In addition, energy efficiency and productivity are achieved at the same time by using a measuring module developed in the field of electric power receiving and distribution.

2.1 Collection of production information by manufacturing execution system
Manufacturing Execution System (MES) is one of the factory automation (FA) solution for visualizing production by linking the shop floor and the
information system, and for the improvement in productivity by driving the Plan-Do-Check-Action (PDCA) cycle.

The concept of the FEMS based on production information is depicted in Fig.1, where the Programmable Logic Controller (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 [4].

The MES interface module, 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 module, interconnection between the shop floor and the information systems is easily established at low cost [5].

2.2 Method for Energy Management
With the FEMS based on production information, 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 (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 module 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 FEMS based on production information provides various types of management solutions to improve productivity and energy efficiency by smoothly driving the PDCA cycle for better energy efficiency.

Fig. 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. 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 the FEMS

This section describes examples of the system configuration with the FEMS based on production information, for three of its four steps, namely: “measurement,” “management” and “visualization.”

3.1 Visualization system for specific consumption

A Web Server module is an embedded data acquisition server that visualizes energy on a Web browser using its Web server function. The main functions of the Web Server module 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 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 the FEMS, 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.

Fig. 5 shows an example of the system configuration using the FA modules. The production information as well as the energy information acquired by the energy measuring module is transmitted via the MES interface module from each equipment to the MES and EMS. In addition, the energy information for the whole line is collected from the CC-Link compatible measuring instruments for various measuring purposes, in the power receiving and distribution equipment and on the panel board, and then transmitted to the EMS via the MES interface module.

4 Examples of the FEMS Introduced in the Factories

As an example of the “measurement”, “management” and “visualization” steps described in Section 3, this section presents the circuit breaker production line at the works.

At the circuit breaker production line, 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

![Fig. 5. Visualization System using Production and Energy Information](image)
deteriorated specific consumption were implemented.

The features of this system are as follows:

1. Energy measurement for each production equipment
   The energy measuring module, which is a PLC module for measuring equipment, 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
   a. Specific consumption for production equipment
      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

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![Fig. 6. Factory Automation and Control Panel](image1)

![Fig. 7. Specific Consumption for Production Equipment](image2)

![Fig. 8. Analysis of Specific Consumption](image3)

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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).

(b) 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.

(c) 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 FEMS based on production information, which focuses on reducing energy in production systems.

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.

References: