Enerize E3 Factory Energy Management System

- For Visualizing the Energy Key Performance Indicator and Achieving Optimal Energy Efficiency -

Katsutomo Tanaka*1 Hiroshi Watanabe*1 Akira Endou*1

The Enerize E3 factory energy management system is the first system in the industry to succeed in visualizing the energy key performance indicator (KPI). This makes it possible to standardize energy management and encourage all members in a factory to participate in energy-saving activities. The system is built by modeling energy supplying utility equipment, and energy-consuming and production equipment. This paper reports its development and features.

INTRODUCTION

Investments in energy saving and renewable energy are growing worldwide. In Japan, a social framework geared towards energy saving and reducing greenhouse gases has been set up through the Domestic Credit System and Green Tax System, the revision and enforcement of the Energy Conservation Act targeting companies as a whole, and so on. The ISO 50001 Energy Management Systems currently being discussed at the International Organization for Standardization (ISO) will standardize energy management and usage and provide global assessment criteria.

In order to keep up with these trends, companies are required to establish a mechanism which enables them to continuously save energy and reduce greenhouse gases with full participation across the organization.

A variety of energy management systems have been commercialized and taken root as Building and Energy Management Systems (BEMSs) particularly in the building automation market. However, such systems for factories and plants are few. Yokogawa has therefore focused on “visualizing” energy in in-plant production activities, and has developed the “Enerize E3 Factory Energy Management System (Realtime Energy Optimizing System Elucidate 3)” to enable such visualization. Enerize E3 is effectively the industry’s first product that can visualize the energy in in-plant production activities.

The Enerize E3 models the energy supply side (energy supplying utility equipment) and the consuming side (energy consuming and production equipment) of a plant, in order to:

• identify waste in energy supplying equipment and quantitative use thereof
• enhance awareness of energy saving in energy consuming departments

ENERGY KPIs FOR CONTINUAL ENERGY-SAVING ACTIVITIES

In order to continually practice energy-saving activities that encourage full participation, indicators that serve as criteria are necessary. Yokogawa defines these indicators as energy key performance indicators (KPIs), and proposes using the KPIs for identifying points where energy can be saved and utilizing them as subsequent management criteria.

The three key points in plant energy management, each of which includes important energy KPIs, are outlined below.

- Recognizing the Energy Flow

As shown in Figure 1, all the energy flows from energy-receiving equipment to the consuming side. Received energy is transformed into another type (electric power, cold and hot water, steam), usable type for downstream equipment, by energy supplying utility equipment, and is then supplied to consuming and production equipment.

![Figure 1 Energy Flow in Factories](image)

In the case of electric power, for example, it is impossible to know the real energy costs and CO₂ emissions without
knowing the energy flow of all of purchased electricity, cogeneration, solar power generation, etc. In addition, equipment efficiency (coefficient of performance (COP), etc.) and operating loss that dominate the energy flow vary from hour to hour according to operating conditions and due to aging. Unless these indicators are recognized in real time, points for improvement cannot be identified. Important energy KPIs here include the real energy cost and CO₂ emissions, and real-time equipment efficiency and operating loss.

- Clarifying the Management Systems of Consuming Departments
  In order to charge energy costs or set targets by department or equipment, the management systems of consuming departments should be clarified. When only one measuring instrument is installed on a floor, the cost need to be allocated proportional to a population or area occupying. Energy costs and CO₂ emissions need to be calculated and managed by each department or equipment. Important energy KPIs in this case are the totalized energy costs and CO₂ emissions of each department and equipment, taking the above mentioned energy flow into account.

- Integrating Energy Flow and Production Flow
  Energy used by production equipment varies depending on the amount and model of products produced. Accordingly, knowing the energy amount alone is not sufficient to analyze actual energy usage. In this case, an important energy KPI is energy consumption per unit production derived by dividing the energy amount by the number of products produced. When multiple models are manufactured in the same production line, energy consumption per unit product by each model is a important energy KPI. If the amount of consumed energy usage can only be known on a lot-by-lot basis, energy consumption per unit product by each lot is important.

ENERIZE E3 SYSTEM CONFIGURATION

Figure 2 shows a typical Enerize E3 system configuration. The Enerize E3 utilizes field data acquired by Yokogawa’s CENTUM distributed control system, Exaquantum plant information management system, InfoEnergy energy management system or other systems as measured energy values. A general-purpose OLE for Process Control (OPC) interface is available, so connection to other systems is easy. In addition, daily- or monthly-report data can be converted to Comma Separated Values (CSV) format for old systems with no interfaces such as OPC, thereby enabling file-based data exchange.

On the other hand, information sources for production results is so-called production management systems, the level of which varies widely. Since no open standards for data exchange with such systems are available, system-specific design and implementation are unavoidable. However, a simplified CSV-format interface is defined in the Enerize E3, and it enables to collect data with minimal file format conversion.

ENERIZE E3 SOFTWARE FUNCTIONS

Figure 3 shows a functional configuration of the software. The lower section of the figure illustrates the flow of data processing by software that runs online on Enerize E3 and storage servers. The data processing flows from left to right, beginning with field data input, through preprocessing computing, energy flow computing, allocating and structural totalizing calculation, and per unit production calculation, and ending with screen display and report printing which are user-interface functions.

Processing procedures are defined through the engineering flow shown in the upper section of the figure and input using a set of dedicated software called builders. The online-execution system performs processing according to the models in the settings database defined by the builders.

The features of “energy supplying utility equipment modeling and energy flow computing,” “consuming department modeling and allocating and structural totalizing calculation,” and “production equipment modeling and per unit production calculation” are explained below. These are essential and characteristic features of the Enerize E3. User interfaces are explained as well.


Energy and energy sources supplied to a factory take a variety of forms, including electric power, fuel oil, and gas. In all cases, energy must be converted into the required form by energy supplying utility equipment. Examples of this energy conversion include transforming voltage to the voltages required by production equipment, converting from fuel oil combustion heat to steam using a boiler and converting from electricity or gas combustion heat to cooling water using a refrigerator. Electricity is supplied by a power company or generated by cogeneration equipment using fuel oil or gas. Thus, even when using the same power of 1 kWh on the consuming side, its cost varies depending on the operating conditions of the energy supplying utility equipment. Since the cost of purchasing electricity differs depending on the time of day, the optimum operating conditions of energy supplying utility equipment vary from hour to hour.

Corporate goals include not only minimizing costs but also minimizing crude oil equivalent values required by the
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Energy Conservation Act and CO₂ emissions, which are a critical global environmental challenge, in view of the social responsibility of corporate activities. The Enerize E3 models complex energy supplying utility equipment as an energy flow and dynamically calculates the cost, CO₂ emissions, crude oil equivalent values, etc. of energy per unit energy traveling through the equipment. Thus, it can clarify these properties of energy supplied to the consuming side. It also calculates indicators used to evaluate efficiency, including coefficients of performance of energy-converting equipment, such as refrigerators and boilers. Consequently, the Enerize E3 visualizes energy loss due to a way of operating equipment and aging degradation of equipment.

The Enerize E3 incorporates Microsoft's drawing tool Visio to describe energy flows. Its builder converts the graphical information of Visio into arithmetic expressions used to compute the cost, CO₂ emissions, crude oil equivalent values, performance coefficients and loss of energy traveling through energy supplying utility equipment. These arithmetic expressions are executed by the online execution system. Figure 4 shows an example of an energy flow for absorption refrigerator described using Visio.

Figure 4 Example of Energy Flow for Absorption Refrigerator

Consuming Department Modeling and Allocating and Structural Totalizing Calculation

Even a building for plant has lighting and air-conditioning equipment and has an energy load similar to that of a usual building. Enerize E3 has a function to allocate a charge for lighting and air-conditioning to each department proportional to the area occupied by each department or the like, so it can clarify the amount of energy usage by department. As shown in Figure 5, organization structure and tables for allocating energy supplied from energy supplying utility equipment are defined using the Enerize E3 builder. The online execution system utilizes the definition information when calculating in real time and "visualizing" the amount of energy used in each organization, the cost of the energy, CO₂ emissions resulting from the energy, the crude oil equivalent values of the energy, etc.

This visualization greatly motivates each organization to save energy and directly links to site-by-site improvement activities.

Production Equipment Modeling and Per Unit Production Calculation

The primary objective of a plant is production, and the energy consumed, energy costs, CO₂ emissions and crude oil equivalent values per unit production are important indicators for the production efficiency.

For each model produced in the plant, the Enerize E3 builder defines the relationships among the processes for
producing the model, production equipment used in each process, and the energy supplied to each equipment. This relationship is referred to as a production model.

Figure 6 shows a schematic mechanism of online calculation. Production results data (which model of product has been manufactured, when, and in what quantity) from a production management system and supplied energy are linked together through the production model. Time-series consumed energy is decomposed according to the time stamp of the production results data, and they are used to calculate the amount of energy consumed, energy costs, CO₂ emissions, crude oil equivalent values, etc. per lot (batch) or a product (unit production).

**Figure 6** Online per Unit Production Calculation

**User Interfaces**

Various types of energy-related information in a plant acquired by the online execution system are presented to the end user through user interfaces. Parties concerned with energy are expanding to every hierarchical level of all organizations within a plant due to growing concerns about global warming, etc. Conventional energy management systems supposed only managers of energy supplying utility equipment to be their users. However, the Enerize E3 assumes a wider variety of people to be its users. They include personnel concerned with production control or production engineering, personnel belonging to general affairs department concerned with plant layouts, and personnel belonging to CSR (Corporate Social Responsibility) departments.

The Enerize E3 is equipped with user interfaces based on the Web mechanism on corporate-wide OA-LAN to respond such use as described above. In addition, dashboard-type screens are provided for the users to freely combine views in order to meet the needs of every hierarchical level of every organization. Figure 7 shows a configuration example of the dashboard-type screen.

Furthermore, each element on the dashboard can be magnified, responding to the needs for data analysis in more detail. Figure 8 shows examples of various type of filters on a magnified display of a correlation analysis graph. Magnifying the screen reveals hidden detailed features and enables the users to configure various settings for display formats, thereby helping the users analyze energy.

**Figure 7** Configuration Example of Dashboard-type Screen

**FUTURE CHALLENGES**

Production equipment modeling functions have been implemented for the first time in version E3 of Enerize as discussed here to allow production energy KPIs to be visualized. In addition to the visualization, the functions such as the prediction and simulation of improvement of effects, the automatic diagnosis of energy-saving points and the control functions directly linking to energy-saving are expected to be implemented in future. We are intending to develop these functions in future and create higher-value added systems.

**CONCLUSION**

In order to identify targets for energy-saving in our customers’ factories and provide them sustainable operation for energy-saving, Yokogawa carries out factory inspection services and engineering services performed by energy-saving diagnostic experts who fully understand factories and plants. We hope to keep offering systems and solutions that deliver excellent results by combining measurement, control, and information technologies.

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