Electric Power Measurement and it's Practical Applications in Green University of Tokyo Project

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Abstract

To achieve the energy saving with sustainable positive intension among participants, the energy flow of equipment must be aligned with the pattern of participants' activities and establish the common understanding among participants. We designed and built a smart electric power metering system, that measures collects and analyzes the electric power chain in the actual building. This paper discusses the following three topics; (1) methodology of measurement in university office, (2) definition of waste, and (3) user interface for system administrator and for residents (such as students).

1. Background

The visualization to achieve the transparency of any activity of equipments and human-being is the first step of reduction of waste in the system. A building or complex has multiple management and control sub-systems, which are independent and isolated from the other sub-system, as a closed system. And, sometimes, these are designed and built by a single vendor. Therefore, neither the end-user (such as building owner) nor co-existing sub-system in the same building can get any data.

Even if the data is available, it is likely a total energy consumption for whole building in a day or a week. With this data, the end-user could not do anything concrete and practical measure for energy saving in the building. Since the end-user has no practical and useful information on detailed information regarding the wastes in the building.

So as to propose and apply an effective and practical measure, the building system should provide the data, from the view point of the end-user. Usually, it is hard to detect or identify what is or which is waste in the system. This is because the activities of people are of wide spectrum and the objectives of residents are also of wide spectrum.

2. Definition of waste and measurement unit

2.1 Identification of waste

In order to run the energy saving measures, we have to identify and to visualize the wastes. The wastes are of transparent among stakeholders regarding the facility, such as building or complex, so as to establish a common understanding and consensus among the stakeholders. Without consensus and common understandings, the performance of energy saving will be very low, since some stakeholders will be in de-lemma.

2.2 Unit of Measurement

The building at an university campus accommodates wide variety of activities, e.g., education, research or administration. The sampling and measurement must be carried out, according to and reflecting the category and ownership of each activity. The following is concrete example of measurement units.

(1) Faculty members
(2) Resident room for students
(3) Room for experiments
(4) Class/lecture room and conference/ briefing room
(5) Server room

2.3 Measuring points

The typical measuring point is a circuit breaker system, whose voltage is 100V and 200V. We also measure the electrical power of 100V outlets for end-user equipment.

2.4 Identification of Waste

(1) Faculty members

We distinguish their time by working time and non-working time, which is called as time-management in this paper.

(2) Resident room for students

There is no concept of working time. We use the benchmarking methodology. We use three benchmarks.

(a) Compare with the past usage pattern
(b) Compare with the other room belonging to the same category
(c) Compare with the top runner room that has most efficient operation.(i.e., the largest energy saving)

(3) Room for experiments

There are many types of equipment, which do not run regularly, such as large scale experimental equipments. The efficiency is evaluated by the actual operation time of the equipments.

(4) Class/lecture room and conference/ briefing room

We evaluate the efficiency and waste, comparing with the schedule and reservation for rooms. There is a room reservation system to identify the room usage intension by the residents.

(5) Server room

The server room is 24 hour times 7 days operation. We apply the same policy as category (2) described above.

3. How identify the waste

In order to encourage and to assist that the residents find out the wastes of energy consumption, we analyze the current data, compared with the past datasets, as described below.

3.1 Time Management Method

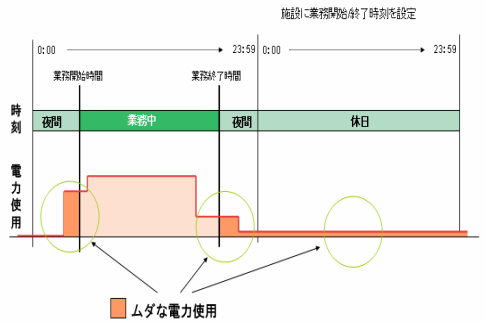

Fig.1 Time Management

Figure 1 shows the concept of time

management. Time slots are categorized into some number of categories, e.g., on-duty, off-duty or holiday. When the equipments and facility is in-operation, it is identify as a waste, since the facility or equipment is used in the time, which was not scheduled to be used.

Fig.2 Working day and holiday calendar

Figure 2 shows the management view of our calendar system, which manages the category of each day as a scope of year. So as to identify the working day of each unit, the operational calendar must be input by an administrator of facility.

3.2 Base-Line Method

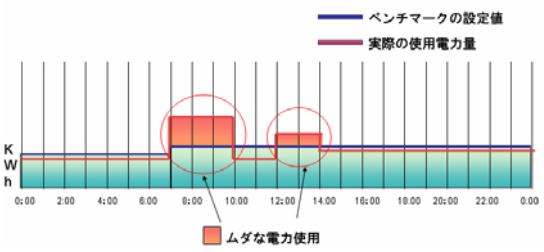

Fig.3 Base Line Method

Figure 3 shows the management view of base-line method. If the power consumption of target equipment or facility went far different from the normal value (i.e., benchmark), the alarm is issued and is counted as waste in the system.

Here, our system can take into account the external parameter to adjust the benchmark. For example, as for the HVAC system, our system can take into account the temperature and humidity of outside atmosphere.

3.3 Operational Status Method

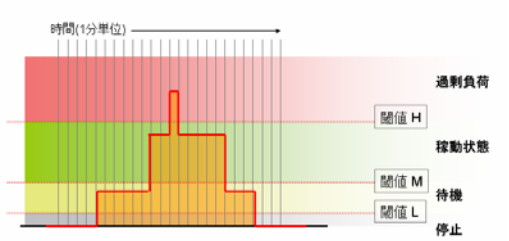

Fig.4 Operational Status method

Figure 4 shows the concept of operational status of some equipment. Many equipments and facility is not simple ON/OFF operation, but is a kind of operation state transition system. According to the state transition, the amount of energy consumption is changed. Through the energy consumption pattern, we could analyze the status of system operation. By this process, we could find out the waste in the system, e.g., work flow has some stacking point(s) in it.

(1) Getting the teaching data

The operational parameters of the system during a one working cycle are monitored to identify the operational status against time. The data, that is got automatically from the system or is got by manually, is called teaching data in our system.

(2) Defining the features for state and for state transition

The volume characteristics in the electric power consumption are analyzed in the time domain. The volume characteristics are basic data characteristics (e.g., average, standard deviation, maximum value, minimum value, distribution, skewness), FFT or wavelet analysis.

(3) Define the hyper space by volume characteristics

Volume characteristics create hyper space by them. The data is evaluated by cluster analysis method so as to identify the volume characteristics vector composed by essential and major volume characteristics. Here, as the simplest case where the dimension of volume characteristics is one, the hyper space corresponds to a threshold value.

(4) Register the coefficient values

The volume characteristics vector and coefficient values for each equipment are registered in the server.

By this procedure, the establishment of teaching value is completed.

(5) Feedback through the daily operation

The environment of the equipment and facility is changed, according the time. Sometimes, the parameters registered into the server become inadequate. Therefore, the system accepts the feedback by the users to adjust and to modify the system parameter. In some case, we can re-run the cluster analysis so that modify the parameter to the adequate value.

In this method, we do use not only the electronic power consumption, but also use other information associated with the target equipment or facility, so as to realize much accurate status identification and evaluation, as discussed in [1],

3.4 Benchmark Method

In benchmark method, the measured data is compared with the model value, which is defined in advance. There are following four methods.

(1) Compare with top runner value

There is the best or ideal efficiency for each equipment, called as top runner. The efficiency of target equipment is compare with the top runner value.

(2) Compare with other sites

There are many sites or equipments in the same category. The efficiency of target equipment is compare with the those value.

(3) Compare with the past data

The system store the archive-able data into the database, to compare the current operational status with the past value. When the significant difference is detected, an alarm is issued to analyze the system.

(4) Compare with the target value

An administrator sets the target value.

4. User Interface

We operates two user interfaces in Green University of Tokyo Project testbed.

One is for facility manager or facility administrator, who has enough knowledge and skill, regarding the facility control and management work. We adopt the Web interface,

and we install the interface software in the dedicated server. By the use of dedicated server, we can improve the system performance (i.e., user response) and security level. The other user interface is for resident, such as students. This system adopts FLASH, so as to provide comfortable interaction between user and the server.

4.1 Web Interface for System Administrator

The commercial web interface is provided by CIMX Corporation. Since the service is based on a cloud computing service, the service has the following features.

(1) Displaying many equipments simultaneously

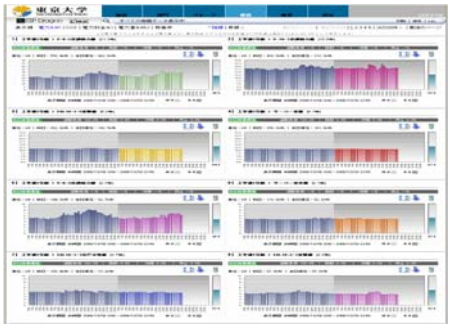

Fig.5 Display view in CIMX system

As a default, the recent two day data is displayed, as shown in figure 5. By this, the user does not need to type in the name of equipment, site, date and other information.

(2) Displaying two day data

In many systems, one day data is shown. However, our system displays two day data, so as to compare the power consumption with the previous day. The administrator easily realize the change of consumption pattern.

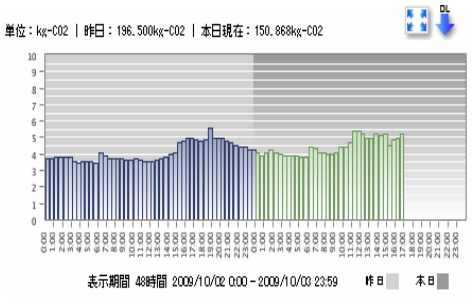

Fig.6 48 hour data displaying

(3) Displaying waste value

Figure 7 shows the waste value displaying view.

The left hand side shows monthly energy consumption, by electricity, electricity bill, CO2 emission, peak electric power consumption, and wasted electric power.

The right hand side shows the data visually. The blue bar at the very end of right side shows the waste ratio in the system.

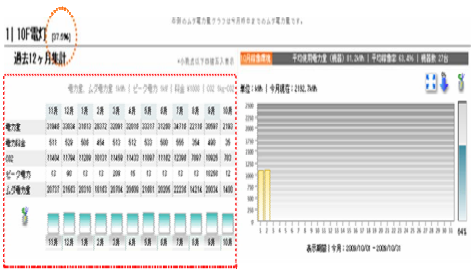

Fig.7 Displaying wastes

Figure 8 shows how the grouping of equipments can be managed. We can define any size of group. The definition is hierarchical, whose hierarchical level is four in our system. These are; all, building, unit, group, equipment.

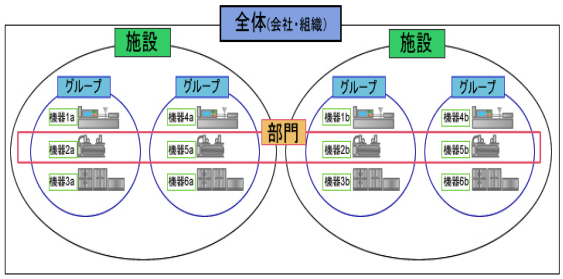

Fig.8 Definition of group

4.2 FLASH interface for residents

The user interface is designed and developed, according to the "Gamenics" principle [2]. The application server running at CIMX Corporation obtain the data from the common data base system operated by Green University of Tokyo Project at Hongo Campus in The University of Tokyo, (Tokyo, Japan). The data is manipulated at the server, so that the client software installed in the client node at the user can refer to.

The top view, when start the management software is floor plan of target facility. In the case of Green University of Tokyo Project, it is building No.2, Faculty of Engineering. See the left side view in figure 10. When the user selects a floor to click, the floor plan of selected floor is displayed in the right side (see figure 10). Simultaneously, the administrators are shown in the bottom with their picture and name. Here, the volume of electric consumption for whole of building, as well as the volume for whole of floor are shown in the view.

Fig.10 Sample View of FLASH interface

Fig.11 Detailed view in FLASH interface

When some particular administrator is selected, the detailed information is displayed, as shown in figure 11. It shows the detailed power consumption for each equipments, such as light, HVAC, display, server, PC, refrigerator, or other equipments.

References

[1] "DIAGNOSTIC METHOD ANALYZING POWER CONSUMPTION OF ELECTRICAL EQUIPMENT", PATENT No . US 716058 B2,

[2] Akihiro Saito, "What is gamenics", Gentosha(幻冬舎社), ISBN 978-4-344-98045-7, July 2007.