Demand monitoring equipment is installed in each factory or office, and is linked to the Mitsubishi Electric Head Office via the intranet, where a centralized monitoring server provides comprehensive control (Fig. 1). The multi-demand viewer uses its wide-area control function to collect electric power data from each site in real time, and sends out an alert e-mail when there is a high probability of exceeding the target level.

1. Introduction
As an aftereffect of the Great East Japan Earthquake, the electric power supply was expected to worsen in the service areas of Tokyo Electric Power Co. and Tohoku Electric Power Co., and thus in the summer of 2011, the Japanese government issued an ordinance on the restriction of electricity use based on Article 27 of the Electricity Business Act. This ordinance mandated that high-volume business users with a contract demand of 500 kW or greater must reduce their use of electricity from 9 a.m. to 8 p.m. on weekdays by 15% from the peak level in the previous summer.

Meanwhile, Mitsubishi Electric announced a plan to reduce demand power (demand) during peak hours. This plan exceeds the government ordinance of 15%; Mitsubishi Electric Group’s 18 business sites, which are subject to the government ordinance on the restriction of electricity use, would reduce the total demand by 25% from the previous year. To achieve this target, each site has implemented drastic electricity-saving measures, and the Head Office has introduced a demand monitoring system to establish a centralized control scheme for the demand power of all business sites.

This paper describes the efforts for reducing power consumption through the demand control system: its implementation, operation, management, and future issues.

2. Demand Control

2.1 What is demand?
Demand power (demand) is defined as the average electric power over 30 minutes, which is calculated by differentiating the electric energy over 30 minutes with respect to time. This time interval of 30 minutes is called the “demand period.”

The basic charge for electricity is calculated from the contract demand, which is determined based on the maximum demand in the last 12 months. In the case of high-volume business users, if the demand exceeds the contract demand, the user is obliged to pay an extra charge as a penalty. That is, demand control is also important from the viewpoint of electricity cost. The integral of the demand (kW) over time gives the electric energy (kWh), and thus it is also useful for energy-saving purposes.

2.2 Electric power control by joint-use restriction scheme
The government ordinance on the restriction of electricity use provides the option of adopting the “joint-use restriction scheme,” which allows a
high-volume business user to coordinate its multiple sites to achieve joint reduction of the peak demand. Mitsubishi Electric employed this scheme to reduce the total amount from all sites.

The joint-use restriction scheme provides two advantages.

First, as long as the total electricity use remains below the limit as defined by this scheme, it is acceptable for a site to exceed its assigned limit value, jointly supplementing the shortfall of the site that would be unable to attain the target of 15% reduction by itself.

Second, joint-use restriction makes it possible for the business user to take comprehensive power-saving measures by fully utilizing individual conditions, such as holidays, determined for each site and supply-demand adjustment contract.

In the joint-use restriction scheme, the peak reference value is defined as the maximum value of the total sum of all sites in the reference year. In general, the peak at individual sites occurs on different days and times, and thus the total sum of the individual peak values within certain hours on certain days is smaller than the simple sum of individual peak values (peak power) (Fig. 2). The greater the number of sites and the wider the relevant area are, the better the effect that can be expected from the deviation in peak day and time. Therefore, Mitsubishi Electric Group pursued operations that take full advantage of the joint-use restriction scheme.

In the joint-use restriction scheme, a target value for the total demand was set for each group of sites within either the Tokyo or Tohoku Electric Power service area, and an individual target demand was also set for each site in proportion to the respective attainable power reduction level. When it is indicated that the total demand will exceed the limit, an alert e-mail is automatically sent out from the system and emergency measures are instructed over the phone to coordinate the sites with higher priority placed on a large site with greater reduction capability.

3. Demand Monitoring System

3.1 Function

This system was established by installing Mitsubishi Electric’s demand monitoring equipment at each site, and a centralized monitoring server at the Head Office, where the demand data from every site is comprehensively managed (Fig. 1).

The demand monitoring equipment and centralized monitoring server are linked via the intranet (MELIT network) and configured in a security-conscious manner. Key functions of the components used in this system are described below.

1. Demand monitoring equipment “E-Energy”

- Using the pulse signal of incoming electricity at each site, the present demand is calculated and monitored every 10 seconds.
- By setting the target demand (upper control limit of demand) and the alert level (for the purpose of pre-alert limit values corresponding to the target demand), an appropriate warning (display, e-mail, buzzer, etc.) is issued in response to the present demand trend.
- Linkage with the present demand enables automatic calculation of the forecast demand (demand forecasted for the end of the demand period) and adjustment power (electric power to be reduced/added to reach the target demand by the end of the demand period) to enable the demand to be promptly adjusted in advance.
- Real-time display of the alert status and demand load graph (Fig. 3), which visualizes the relationship between the present demand, forecast demand, target demand and alert level.
- Through linkage with Mitsubishi Electric's...
web-compatible G-150AD air conditioner controller, air conditioning can be automatically controlled in response to the demand load.

Figure 3 Demand load curve

(2) Centralized monitoring server (Multi-demand viewer)

The centralized monitoring server for demand monitoring is integrated with the newly developed wide-area demand monitoring software.

- Data on power demand and alert status is collected every 10 seconds from E-energy equipment at all relevant sites through http communication, and is displayed in a list by the web browser (Table 1).

<table>
<thead>
<tr>
<th>Measured values</th>
<th>Display item</th>
<th>Demand time</th>
<th>Update interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30 minutes</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Present demand</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Forecast demand</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Adjustment power</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Previous demand</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Remaining time</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alert status</th>
<th>Display item</th>
<th>Demand time</th>
<th>Update interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-stage alert</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Fixed alert</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Over-limit alert</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
<tr>
<td>Target demand</td>
<td></td>
<td>◎</td>
<td>Fixed</td>
</tr>
<tr>
<td>Alert level</td>
<td></td>
<td>◎</td>
<td>Fixed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication error</th>
<th>Display item</th>
<th>Demand time</th>
<th>Update interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication fault</td>
<td></td>
<td>◎</td>
<td>◎ 10 seconds</td>
</tr>
</tbody>
</table>

- To comply with the ordinance on the restriction of electricity use, which is determined based on the electric power in one hour, the demand values for a demand period of 60 minutes are also calculated.

- The total sum of the demand data is automatically calculated for a group of multiple sites (e.g., in the service area of a certain electric power company).

- By setting the target demand (upper control limit of demand) and the alert level (pre-alert limit value for the target demand), alert e-mails are broadcast when necessary.

- The newly developed multi-demand viewer provides not only a display screen for the wide-area demand monitoring but also the capability to achieve integrated control by collecting and accumulating various demand and electric energy data for each group of sites (e.g., in the service area of a certain electric power company) including: demand forecast of the day, photovoltaic power, and peak demand (forecast) of the day.

- Demand data is collected from the E-Energy equipment at each site every 30 minutes by using http communication, and is stored as daily log files.

- This demand data is used to prepare a trend analysis with automatically generated graphical representations and daily, monthly and annual reports.

- Capable of grouping multiple sites, as well as comparison and analysis on a site-by-site basis.

3.2 Features

The key features of this system are easy web-based maintenance, and various kinds of support with multiple types of alerts for preventing the demand from exceeding the limit.

(1) Web-based visual demand control

- Operation can be easily started as no special software is required by the control PC for demand monitoring; a web browser is sufficient. Since web browsing is available at any point on the intranet, it is possible to monitor the demand from a remote location. Various settings can also be easily made on the web screen.

- The web screen is automatically updated, and thus by simply keeping the web browser running, information about the demand trend (up or down trend) is always available.

(2) Alert in the case of anomaly

To quickly respond to an emergency situation and to restrict the demand, this system provides the following four types of alerts that are ready to be activated at any time in response to the monitoring system. If one of these alerts is activated, the occurrence status is displayed on the control screen, and depending on the type of alert, an appropriate e-mail is automatically sent out to the occurrence site and the concerned personnel at the Head Office.

First-stage alert: When the forecast demand exceeds the target demand

Fixed alert: When the present demand exceeds the fixed alert level

Over-limit alert: When the present demand exceeds the target demand

Communication error: When communication with an individual site fails

In actual operation, however, the telephone is also used to ensure a clear understanding of the situation and for other communication purposes, and as long as there is a margin between the total electricity use of all sites and the limit, operation rules are applied in a
flexible manner, such as "wait and see" even if an alert has been issued.

4. Power-Saving Effect by Demand Control

4.1 Power-saving effect

As a result of the power-saving efforts at each site and fortunately due to a cooler summer than the previous year, the target 25% reduction from the previous year was achieved for the total use of electricity throughout the summer of 2011 in both the Tokyo and Tohoku Electric Power service areas. In August, by optimizing the balance between the target values of all sites, improvements for reducing excessive burden were implemented so as to minimize the use of engine generators and normal shift operation was resumed. The power-saving measures also reduced the use of electric energy, achieving energy saving and CO₂ reduction equivalent to a 19% reduction of incoming electric energy compared to the same period in 2010. The greatest achievement was brought about by thorough operational management and conversion to LEDs and other high-efficiency devices, resulting in significant power saving for lighting, air conditioning and production equipment, which accounts for 16.5% of the total power-saving achievement (after adjusting for the temperature difference from the previous year).

The second largest power saving was achieved by using the photovoltaic power generation system. As one of the power-saving measures for the summer of 2011, about 2 MW of photovoltaic systems were newly introduced. The results of photovoltaic power generation at all sites confirmed that an output of 80% or greater of the rated value can be expected during sunny days.

This time, the reduction target was very challenging, and thus each business site was forced to take drastic measures including the following modifications to the production and work shifts:

1. Rotating shift operation; shifting production to off-peak hours, holidays, or nighttime.
2. Shifting project execution timing from the summer-time to the second half of the fiscal year (modification of annual business plan)
3. Shifting production to other areas (transfer of equipment, relocation of employees)

Although these measures brought significant positive effects, considering the anticipated long-term nationwide power shortage, measures 2 and 3 would be difficult to continue as they are implemented in the coming winter and after for power-saving purposes, and thus detailed coordination will be required in advance.

4.2 Operational issues

(1) Demand control with weather information taken into consideration

The analysis of daily demand data indicates that its changing pattern is quite similar to that of the daily maximum temperature (Fig. 4). The influence of the weather (amount of sunshine) is also significant, especially where the photovoltaic power generation system is also used. Thus, an important factor for future operations will be the daily demand forecast and target control taking into consideration the weather forecast and the electricity forecast released by the electric power company.

![Fig. 4 Relationship between site total demand and temperature (within the service area of Tokyo Electric Power Co.)](image)

(2) Demand control utilizing photovoltaic power generation system

It has been confirmed that for power control in the summer, it is effective to consider the use of photovoltaic power during the daytime. In the case of an office-type business site where the largest photovoltaic system is installed in proportion to the contract demand (Fig. 5), the peak use of electricity occurred at 11 a.m. or 2 p.m. in the same way as at other sites, whereas because of the photovoltaic power generation, the peak of commercial power occurred in the evening when it was getting dark.

As shown in this example, at office-type sites where the change in electricity use is slow and day-to-day variation is small, photovoltaic power generation is expected to be effective for preventing the concentration of electricity use and saving power by shifting the time of peak power. To achieve this result, however, a certain facility size is needed in proportion to the contract demand (electricity use), and careful examination is required considering the cost, installation area, etc.

5. Conclusion

In the summer of 2011, not only Mitsubishi Electric but every member of society worked hard to conserve power, resulting in a greater-than-expected contribution to power reduction in the Tokyo and Tohoku Electric Power service areas.
However, the shutdown of nuclear power plants is now a nationwide issue; people are worried about power shortages not only in the Tokyo and Tohoku service areas but also in the Kansai, Kyushu and Shikoku Electric Power service areas. The power supply and demand situation is expected to remain severe in Japan for the foreseeable future. In the area where the Mitsubishi Electric Group has many large-scale production sites, power-saving measures must be urgently introduced. To cope with the risk of electric power shortages, Mitsubishi Electric expanded the introduction of the demand monitoring system through the summer of 2012. The system has now been introduced in all high-volume users of the group, a total of 68 business sites, and a scheme to cope with a potential nationwide power shortage has been built. In addition, the know-how acquired through the experience of reducing the peak power will be used for planning and implementing the measures for saving energy (electricity use reduction) and reducing CO₂.