Smart Community Demonstration Projects
- Initiatives in Keihanna and Malaga for EV Management -

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For the promotion of low carbonization and energy conservation in cities, it is important to introduce effective equipment to improve efficiency in each phase of the "generation, transmission and consumption" of energy. In addition, the establishment of a system that can monitor states of energy supply and demand, and balance them through ICT management (smart community concept), has been attracting attention of late. In Keihanna and Malaga, we started social demonstration projects as a step toward a total management system for optimizing whole-city energy consumption. These projects place particular focus on smart technologies in the transportation sector, which is now seeing innovation due to the progress of mobile networks and new electric vehicles. This document explains the initiatives and prospects for the project.

1. Introduction

The demonstration projects of Keihanna and Malaga are being performed in Kyoto prefecture, which is home to Kansai Science City, and the Malaga district in Andalucia state on the Mediterranean in Spain. The two cities are two of the model cities of the smart community, the demonstration experiments of which are being conducted globally. In particular, the demonstrations being performed in the two cities focus on energy management in the road traffic field.

Both demonstration projects are funded under national projects. The Keihanna demonstration project is being undertaken as a subsidized project of New Energy Promotion Council, NEPC (only in fiscal year 2010, undertaken as a commissioned project from New Energy and Industrial Technology Development Organization, NEDO). The Malaga demonstration project is being undertaken as a commissioned project from NEDO. The Keihanna demonstration project plays the role of "domestic demonstration" to verify our base technologies, while the Malaga demonstration project is an "applicable global demonstration" as a showcase. **Table 1** shows the schedule of the two demonstrations.

Table 1   Schedules of the two demonstrations

	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
Keihanna demonstration	Start of system operation (March 2012)					
Malaga demonstration		Start of system operation (April 2013)				

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The common themes of the two demonstration projects are the establishment and operation of the electric vehicle (EV) infrastructure (i.e., EV chargers and their management server system) for allowing a large number of EVs to be accepted in a community, as well as initiatives for energy management related to EVs. An overview and the current status of the two projects are explained below.

2. Overview of Demonstration Projects

2.1 Keihanna Demonstration Project

In April 2010, the Ministry of Economy, Trade and Industry chose domestically four areas (Yokohama city, Toyota city, Keihanna Science City (Kyoto prefecture) and Kitakyushu city) as the target areas of for the "Next Generation Energy and Social System Demonstration" that was an activity for the establishment and global development of the Japanese smart grid (smart community). The demonstration project presented here is to perform demonstration experiments in Keihanna Science City among these four areas, and is an activity subsidized by the Ministry of Economy, Trade and Industry. The Next Generation Energy and Social System Demonstration is an activity that demonstrates the smart community in actual fields, including not only the transportation sector, but also the residential sector and the commercial sector. It features the introduction of the community energy management system (CEMS) for supervision of the sectors and optimization of energy utilization in the community (**Figure 1**).

The Next Generation Energy and Social System Demonstration in Keihanna Science City (hereinafter referred to as the Keihanna demonstration project) includes Kyoto prefecture and also involves twenty-four companies, local governments and universities. Among them, Mitsubishi Heavy Industries, Ltd. (MHI) is involved in the demonstration of the transportation, residential, and commercial sectors as the managing company leading the demonstration project. In the transportation sector in particular, MHI is in charge of the demonstration of power management for charging EVs using 100 vehicles.
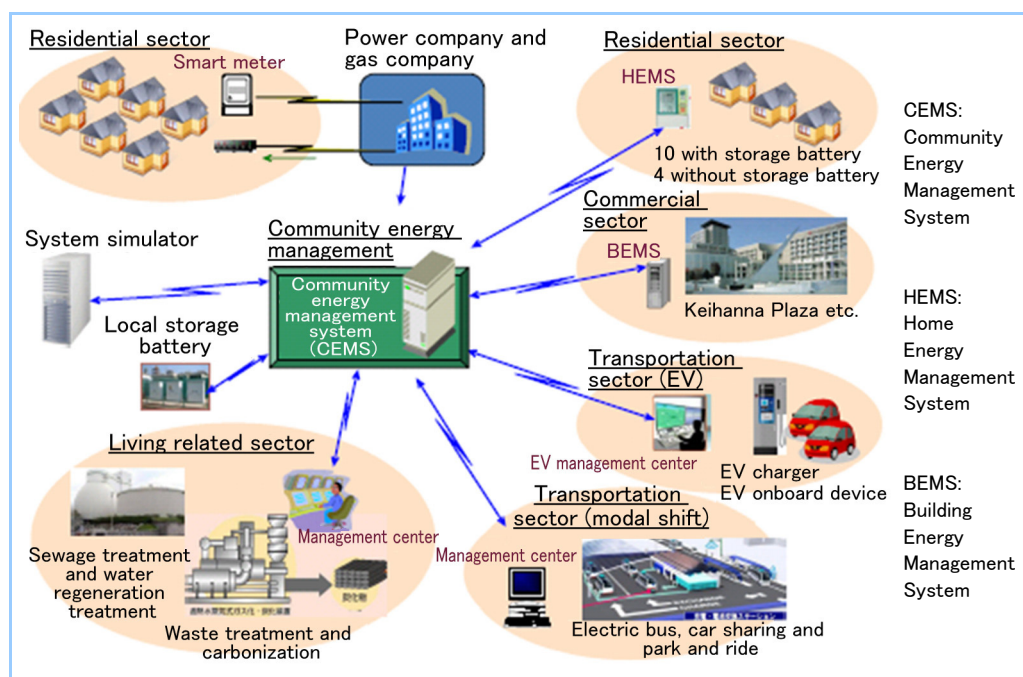

Figure 1 Keihanna demonstration

2.2 Malaga Demonstration Project

This demonstration project is a Japan-Spain joint demonstration project based on the Japan-Spain Innovation Program (JSIP), which is a technological development cooperation agreement that was concluded between NEDO and the Industrial Technology Development Center of the Spanish government (CDTI) in December 2008. The project intends to introduce Japanese technologies related to the smart community and demonstrate their effectiveness in a European city that is leading the way in the introduction of a system to resell electric power and the utilization of a large quantity of renewable energy.

Through this demonstration, MHI aims to allow the demonstrated package to advance to a standard smart community system in Europe by developing the latest outcomes of the Keihanna demonstration on an as-needed basis, and by cooperating with the local governments in the demonstration area and influential European power and communication companies (**Figure 2**).
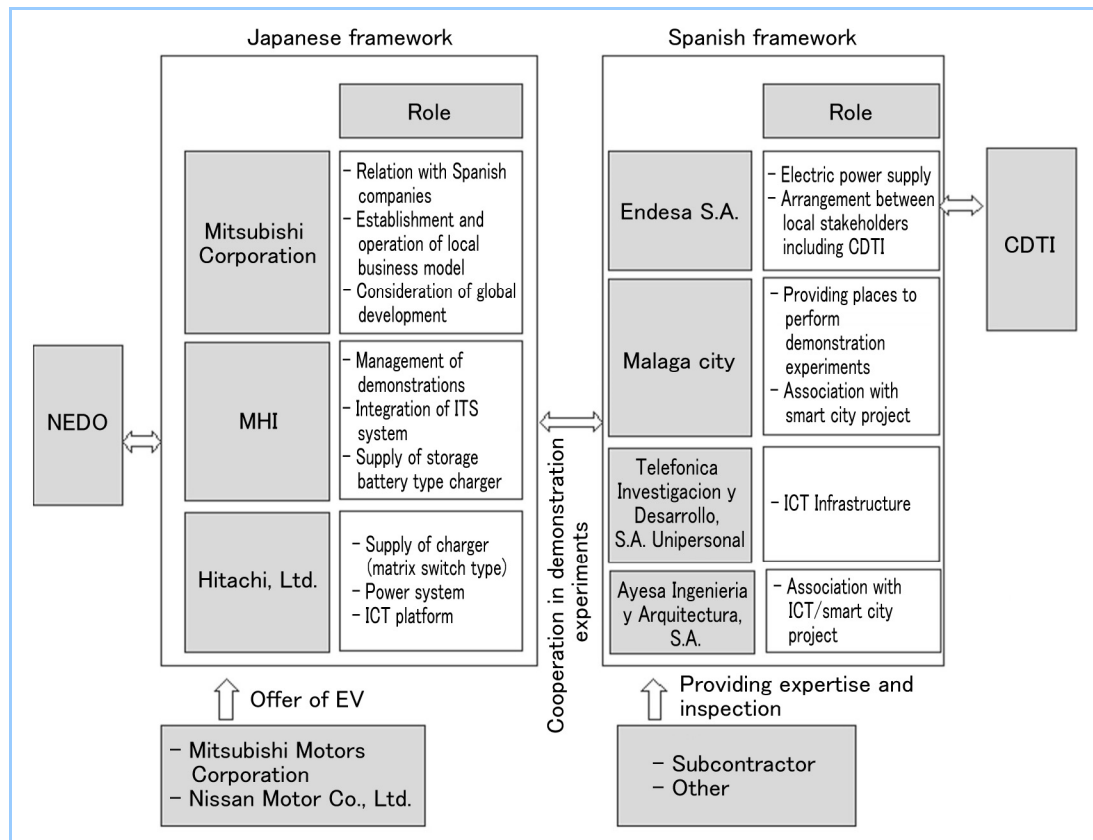

Figure 2   Cooperative structure

This demonstration project is roughly divided into four items:

[1]   ICT management of EVs and charging infrastructure
[2]   EV power management
[3]   Information platform of smart community
[4]   General services

Item [1] is the demonstration of ICT management for road traffic where EVs and the charging infrastructure (i.e., charging station) on the road network are moved online and then managed and analyzed by the center.

Item [2] is an initiative for offering the monitoring of power consumption results, prediction of power demand and control of the power supply and demand balance to EV drivers and charging station operators that are new power users, with a focus on EVs, which are movable power users, and charging stations, which are power supply bases.

Item [3] is the demonstration of the platform that will play the role of the information infrastructure for the integrated management of utilities (services related to electric power, transportation, heat, water municipal waste, etc.) in future smartification based on the smart community concept.

Item [4] looks for the possibility of new services for drivers and operators through the analysis, processing and distribution of various pieces of information accumulated in the management system of the smart community in items [1] to [3].

In this demonstration project, MHI has compiled items [1] to [4] above in general and demonstrates items [1], [2] and [4] of the transportation sector.

2.3   Comparison of Demonstration Projects

Table 1 shows the schedule of the demonstration. The two demonstration projects share the rough commonality of being smart management of EVs, but they are differentiated based on demonstration conditions (the characteristics of demonstration area and duties shared with partners

in each of the two), etc. In the Keihanna demonstration project, from the perspective of demonstrating the energy management of the whole area, a demonstration related to the whole area is being undertaken also in the transportation sector, including the monitoring of public normal chargers and modal shift. On the other hand, in the Malaga demonstration project, power suppression for quick chargers and the optimization of power reception have been initiated. **Table 2** compares the two demonstrations.

Table 2   Rough comparison of the two demonstrations

| | Smart management of EV infrastructure | | Power demand management | |
	Introduction and operation of EV infrastructure	Establishment of supervision system	DR[*1] to end user	DR[*1] to intermediate user
Keihanna demonstration	Done	Done	Done	N/A
Malaga demonstration				Done
Description	- Introduction and operation of EVs, charging stations, onboard systems, etc., in demonstration field	- Establishment of a server that supervises EV infrastructure, and analysis and utilization of the collected information	- Prediction of charging action of drivers who are end users of EV power and control of their consuming behavior	- Request to charger operators that are intermediate users of EV power for control of the supply

| | Demonstration of chargers | | | Improvement of onboard system | Modal shift | Remarks |
	Variable power control of quick charger	Monitoring of normal charger	Optimization of power reception of quick charger			
Keihanna demonstration	Done	Done	N/A	N/A	Done	- Items performed by another company in the consortium are omitted - Items outside the transportation sector that are performed by MHI are omitted
Malaga demonstration	N/A	N/A	Done	Done	N/A	- Items performed by another company in the consortium are omitted
Description	- Making the charging power from a quick charger to an EV variable at any time for flattening of the power level	- Use of information from the vehicle for understanding charging actions at home, etc., in addition to charging at a quick charging station	- Optimization of charging and discharging to/from fixed storage batteries for minimization of power reception from the system	- Introduction of onboard equipment equipped with an acceleration sensor or a navigation system using a smartphone and demonstration of their functions and usability	- Study of traffic demand and economic effects due to possible introduction of public transportation such as electric buses	

*1   DR is an abbreviation for Demand Response, which is an initiative to control power consumption using any means as needed following a comparison between the state of the power supply and the predicted consumption of the power demand.

3. Overview of Demonstration System

For the demonstration of the two projects, MHI developed and manufactured equipment necessary for their infrastructure and the basis of the demonstration itself. Some of this equipment is presented below.

(1) Quick charging station

The EV quick charger used in these demonstrations is a charger based on the Japanese CHAdeMO standard that aims to prevail widely as a global standard. MHI has adopted the DC link system and a stationary type storage battery system, and MHI is the sole supplier who can provide such distinctive features as standard.

This combines MHI's stationary lithium ion storage battery with a standard CHAdeMO quick charger and consists of an EV charging system and a stationary storage battery charging/discharging system connected through a DC bus line to an AC/DC converter that converts AC power supplied by the power system to DC. In addition, this charger can be equipped with an optional photovoltaic (PV) system connected through a DC bus line (**Figure 3**) for the effective use of photovoltaic energy for quick charging of EVs (only in the Keihanna demonstration).

By devising the structure in this way, the power purchase costs for quick charging can be reduced through storing daytime power generated by the PV system and cheaper midnight power, and utilizing the stored power for quick charging of EVs. In addition, a function that enables the use of the stationary storage battery as an emergency power supply in times of disaster such as an earthquake have been added.
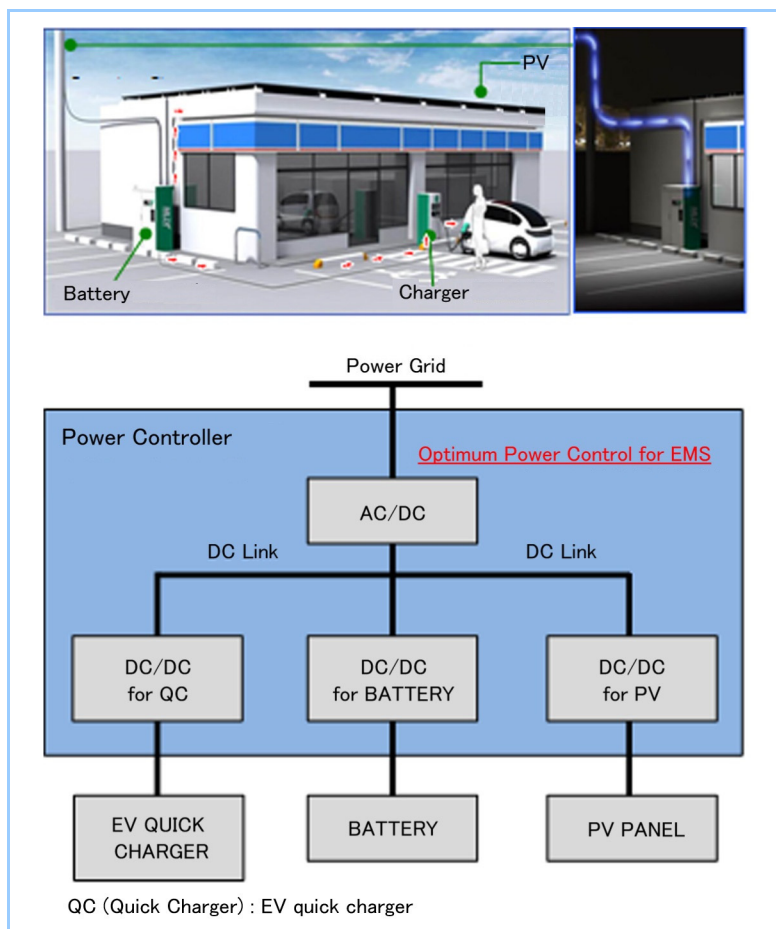

Figure 3   DC link quick charger with storage battery

(2) Onboard system

To monitor and control the movement of vehicles, which are the main constituents of road traffic, equipment that enables interactive communication between the vehicle (driver) and the center is required. To motivate drivers to introduce onboard systems to their vehicles, the delivery of useful information (contents) and onboard communication devices that can refer to

the information on the vehicle in real time are necessary. When affordability is required, the use of a smartphone is an effective way to realize such a device. When high performance and high reliability are required, on the other hand, dedicated onboard equipment is needed.

In the demonstrations, in addition to the concept models of dedicated onboard equipment , simple onboard systems based on smartphones are also used based on the current trend (refer to 4-3-(2)).

The dedicated onboard equipment employed for the demonstrations has functions of remote communication with the center system (management system) through the mobile phone network, automatic linking to a smartphone in the vehicle through Bluetooth communication, GPS positioning, data collection through connection to CAN BUS (onboard LAN) and other features.

(3) Management system

Although many management systems connecting vehicles and the center system through the mobile phone network (telematics) have been experimented on and some were commercialized in the past, their use was limited because of the high communication cost, difficulty in securing a constant power source and the necessity for case by case handling, such as wire routing in the installation of equipment and interconnection with onboard communication. In recent years, however, these issues have been resolved by improvements and cost reductions in the mobile phone network, and the release of EVs.

In these demonstrations, a comprehensive management system with cooperative functions that link widely to the EV infrastructure such as quick and normal chargers, their charging quantity accounting systems, xEMS (various energy management systems), etc., in addition to telematics between EV onboard equipment and the center system, have been established. This management system assumes cooperation with other smart systems on the upstream side and seamless linkage (M2M (Machine to Machine), etc.) to devices in other fields on the downstream side.

The center system machine has a scale-out configuration and supports cloud computing so that it can correspond to an increase of vehicles in a scalable manner. In addition, measures for ensuring security against access from public networks such as encryption, layer separation, access detection, etc., have been undertaken. **Figure 4** shows a schematic representation of the EV management system used for the Keihanna demonstration project.

Furthermore, the Malaga demonstration project employs load sharing and redundancy in further consideration of the capacity necessary for processing a large quantity of data as social infrastructure. Therefore the management system has a larger scaled configuration that includes a data warehouse for the utilization of mass data and BI (Business Intelligence) tools.
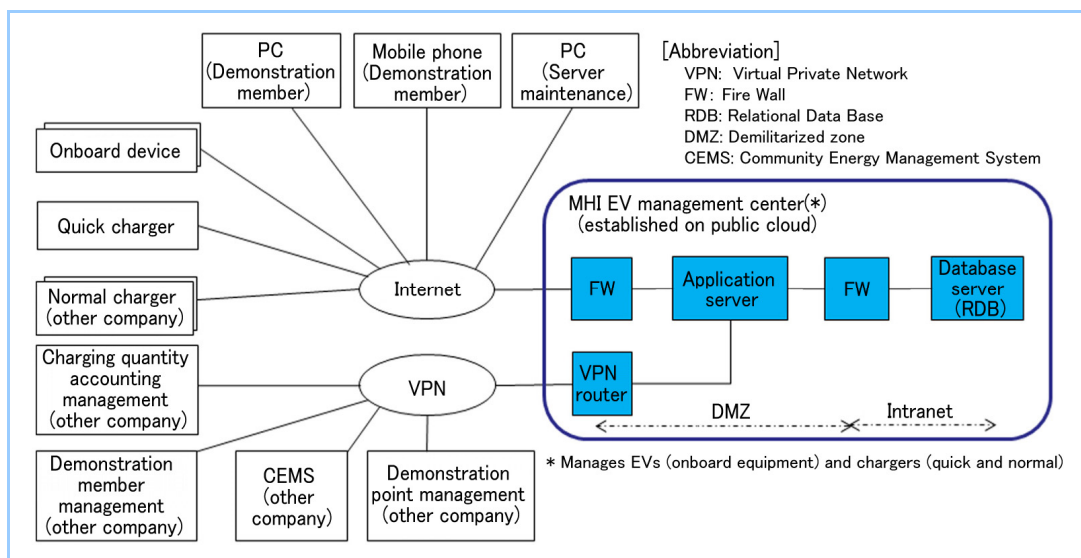

Figure 4   Schematic representation of EV management center (Keihanna)

4. Contents of demonstrations

Both of the two demonstrations are under way (as of September 2013). Some of the contents that were demonstrated in the past and that will be demonstrated in the future are presented below.

4.1 Management of Power Demand

4.1.1 General Background

When suppliers supply items or services, generally they determine the supply amount depending on consumer demand. Provided, however, that the benefits to the supplier and a consumer do not conflict, the consumer's behavior may be changed by telling the consumer the supplier's requests. In the power field, this mechanism of regulating supply and demand through information delivery and encouragement to the consumer is referred to as the demand response (DR).

It is necessary for power utilization to maintain the supply and the demand balanced at all times (simultaneous same amount control). In the past, simultaneous same amount control was attained by regulating the supply amount on the power supply side depending on the demand. However, it is predicted that regulation only from the supply side will be difficult due to elements such as the separation of electric power generation and transmission following electricity deregulation, the relaxation of the regulations of power generation business and the introduction of a large quantity of renewable energy in the future.

In addition, because the spread of a large quantity of EVs will lead to additional power demand, and they are not positionally or temporally fixed consumers, difficulty in maintaining the supply and demand balance will be caused.

For these reasons, it is believed that demand response corresponding to EV power demand will be required.

4.1.2 Keihanna Demonstration

(1) Background and purpose

In the Keihanna demonstration, the CEMS described above aggregates the predicted power demand of the residential sector, commercial sector, transportation sector, etc., and the predicted power generation of the PV to calculate the optimal power demand for that area, and informs each sector of the optimal power demand as the target demand. Each sector controls power demand according to the target demand. In this project (transportation sector), timing changes or EV charging restraint is requested to EV users according to the target demand informed by the CEMS.

This request is sent to EV users basically using email. However, onboard navigation devices or a web browser can be used as the user interface. The requests to EV users are not imperative. However, incentive points are given to EV users who have followed the requests (**Figure 5**). The objective EV users of this demonstration are individual or corporate participants who have applied for this demonstration in advance and who live in the Keihanna district (Kyotanabe city, Kizugawa city or Seika-cho).
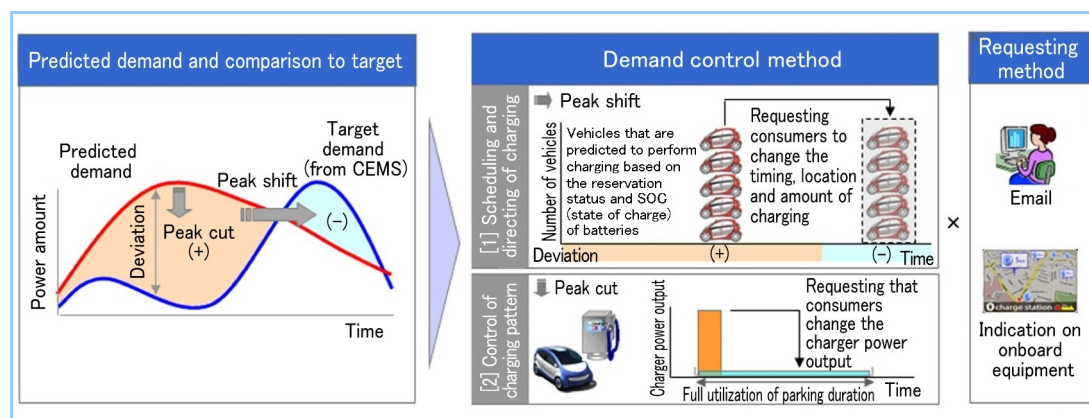

Figure 5 Control of EV power demand

(2)   Current state of demonstration

The Keihanna demonstration started in FY2010 and will last five years. The infrastructure used for this social experiment is basically the same as the system used for the Malaga demonstration. System operation began in March 2013.

This demonstration system measures the charging power using probe information from the EV onboard system. Probe information represents positional information, vehicle information, sensor information, etc., sent from the vehicle or the communication terminal installed in the vehicle. The probe information in this demonstration contains the state of charge (SOC) information. Among over-time changes of SOC, increasing portions are considered as charging and the charging amount is calculated accordingly. By measuring charging power amount with the probe data, charging conducted not only at charging stations connected to the center system, but also at private houses or normal public charging spots can be understood.

EV charging tends to be performed as normal charging after 11 p.m. using midnight power. It is also found that there are spikes in demands caused by quick charging during the daytime (**Figure 6**).

Additionally, the DR demonstration aiming at peak shifts and cuts of EV charging power started in December 2012. In the demonstration in FY2012, by requesting that EV users restrain charging behavior in the specified time zone through email, an approximately 10% to 20% peak shift/cut rate in that time zone was attained. However, because this DR effect has too large a daily variation, it is necessary for the establishment of an EV charging power management method to conduct continuous demonstrations to clarify the controllable factors caused by human behavior.
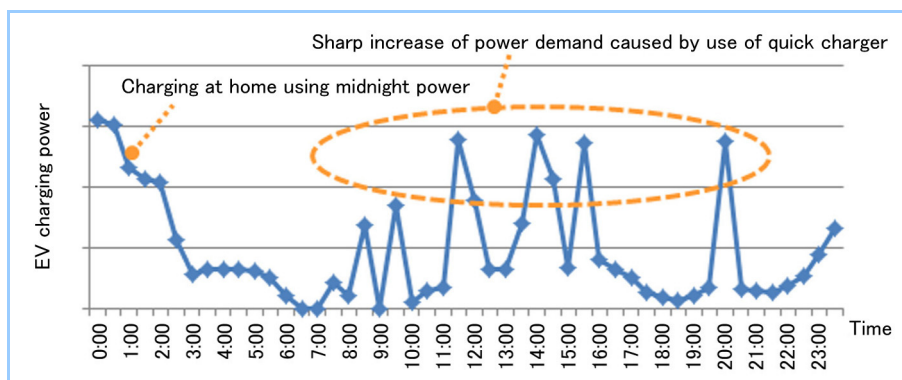

Figure 6   Trend of EV charging in demonstration

4.1.3   Malaga Demonstration

(1)   Background and purpose

The Spanish government has announced its target of 250,000 EVs in the country by 2014, and promotes programs related to the promotion of EV use, research and development, as well as the development of the charging infrastructure, in order to achieve this target. In Spain, 50% of the total travel amount related to the transportation of people and goods occurs in cities and their suburbs. Therefore it is expected that the introduction of EVs can be efficiently promoted by developing the charging infrastructure intensively in these urban areas.

However, if EVs and the charging infrastructure increase sharply in closely spaced areas, the power company may face the issue where the destabilization of the regional power supply network may result and the charging infrastructure operator will suffer the risk where power demand concentrated into a certain area or time zone may exceed the capacity of the power supply or reception at the charging stations. For these reasons, it is necessary to predict the demand of EV charging in each charging station correctly. If it is expected that the supply and demand balance cannot be maintained, a system that disperses the power demand in real time using any method is required.

(2)   Current state of demonstration

In the Malaga demonstration, MHI has cooperated with the Endesa Group, a Spanish power company, and has jointly started consideration of a mechanism dedicated to the stabilization of the power supply and demand balance.

For EV power management, power suppliers (i.e., power generation company, power transmission company and power distribution company) request "stabilization and security of power network interconnecting charging stations" and "high operation rate and high stability of the charging infrastructure." In other words, they spur EV power demand while requesting its temporal and spatial leveling.

On the other hand, EV drivers, who are power consumers, basically expect that they be allowed to use a charging station without restriction on time, place or charging amount. However, this results in the situation where EV drivers would rather avoid the inconvenience caused by competing with other users, or in reluctance to pay higher charging fees compared with charging stations in areas with a power allowance.

In this project, drivers are informed of the requests of power suppliers using onboard equipment to induce them to change their behavior. Such requests to drivers are delivered as recommendations by a method using the Internet such as an email or a portal site. In some cases, as an incentive to change behavior, valuable points are given to users who follow the request (**Figure 7**).

It is expected that such a management system for changing behavior can be applied in the future, not only to EV power management but also to the entire transportation field. MHI plans to establish and verify a mechanism that generally motivates drivers who are the main movable constituents of transportation as well as the main consuming constituents.

In the Malaga demonstration project, MHI is considering a mechanism that requests that not only EV drivers, who are end power users, but also charging station operators, who are intermediate consumers, restrain the use of electric power. In this way, a mechanism that can require quick charging stations covered by the management system to suppress power output or temporarily stop operation in response to a request from power suppliers will be established and then verified in the demonstration.
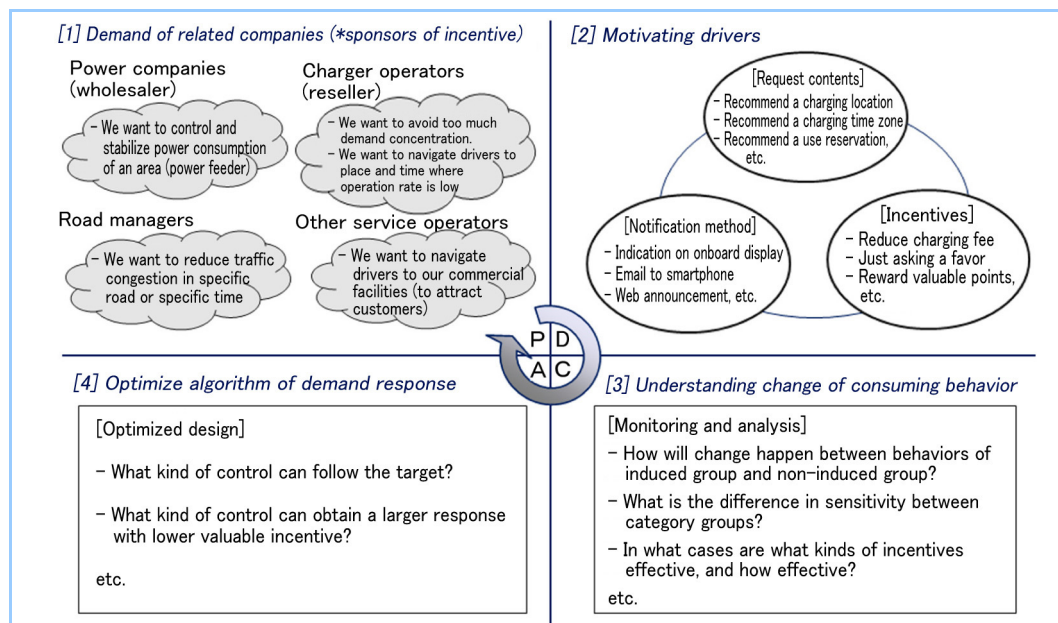

Figure 7   Demand response

4.2   Demonstration for EV charger
4.2.1   General Background

In the demonstrations, the value-added quick chargers described above have been introduced and their usability and operability are being evaluated. In addition, the electrical characteristics of the charger itself will also be evaluated in this demonstration.

4.2.2 Demonstration in Keihanna
(1) Variable power output control of quick charger

In the Keihanna demonstration, each quick charger is equipped with a function that allows an EV user to select charging power output from High (max 33 kW), Medium (max 20 kW), and Low (max 10 kW). This function intends to attain peak cuts by requesting that EV users suppress charging power output in consideration of the load on the power system during quick charging in response to a possible tight supply and demand balance. Furthermore, when multiple quick chargers in a charging station operate simultaneously in the future, this variable power output control is an effective technology that allows for cooperation between the chargers, and the suppression of the power reception to the capacity of the facility or lower.

(2) Understanding of normal charging behavior

There are two types of chargers used: the quick chargers and the normal chargers. The quick chargers have been introduced by MHI and their charging behaviors are being evaluated. In addition, the normal chargers introduced in the Keihanna demonstration are connected to the management system and their charging data are also being collected and evaluated. MHI obtains knowledge for optimum charging infrastructure development by managing the data collected from both quick chargers and normal chargers.

4.2.3 Demonstration in Malaga
(1) Optimization of power reception of quick charger

MHI plans to control the power storage amount of internal stationary storage batteries in quick chargers depending on the time or situation. That enables the leveling of peaks and valleys of power reception over a day (or a year) and then the reduction of power receiving contracts (i.e., maximum power reception). In addition, the total power reception from the power system and the corresponding electricity cost can be suppressed by minimizing the loss from charge and discharge to/from the storage battery.

As a result of these optimizations, the large power receive contract and the cost for the reinforcement of the power system that were required for quick charging become unnecessary, and the initial costs of quick charging station operators can be reduced.

4.3 Enhancement of onboard system

The common onboard system used for demonstration is as described in item (2) of section 3. In the Malaga demonstration, "high performance models in anticipation of developmental application" and "a configuration utilizing a smartphone that anticipates the need for cheaper systems" are also being demonstrated.

(1) High performance model

This onboard system incorporates an acceleration sensor and a gyro sensor and enables the center system to perform matching of the obtained data on an electric map, and then record or reproduce the driving characteristics. Based on this system, new applications for automobile insurance, etc., including the reproduction of accidents and safe driving evaluation, can be developed.

(2) Smartphone cooperation model

In recent years, the functions of smartphones have been enhanced. For some applications, a smartphone can be used for the functions of an onboard system. Therefore MHI will verify the possibility of replacing an onboard system with a smartphone in the demonstrations. Specifically, the following will be verified by collecting vehicle (CAN) data and installing on the vehicle an OBU (On-Board Unit) that can transfer the collected data to the smartphone.

[1] Smartphone linkage application that communicates with the OBU automatically upon entry of the smartphone into the vehicle, and also works as a display device

[2] Affordable support functions utilizing a general purpose navigation API (Application Programming Interface), etc.

[3] Simple configuration of a single unit of a smartphone or a smartphone with additional simple equipment that performs the major functions of the onboard system
Based on these verifications, MHI will appeal to users about the advantages of installing an onboard system that can offer attractive contents at a moderate price.

4.4 Modal shift

To achieve a reduction in carbon emissions and energy saving in the transportation sector, a modal shift from private vehicles, etc., to a low carbon transportation system such as public transportation, etc., is indispensable. In the Keihanna demonstration, MHI investigated the actual conditions of transportation in that area and created a traffic demand model based on a method of transportation engineering to establish a planning method to design a low carbon transportation plan suitable to the regional characteristics. The creation of the traffic demand model used a method of disaggregate modeling (logit modeling). This is a way of thinking in which the transportation method is selected from multiple choices depending on the effectiveness of each, based on the principle that the occurrence of traffic is caused by people themselves. This traffic demand model can be applied to anywhere, not only to Keihanna Science City, provided that the actual conditions of transportation in that area can be understood.

5. Conclusion

Both the Keihanna and Malaga demonstrations have completed the building of the infrastructure, and the acquisition and analysis of the data has commenced. As a result, a large quantity of data will be accumulated in the management center. Therefore the anticipated future issue is the analysis and utilization of the large amount of transportation data. In addition, the efficient processing of a significant amount of telematic transactions will be required.

Similarly to the spread of Internet terminals to families and mobile terminals to individuals, it is expected that communication terminals for vehicles will rapidly spread within a few years. Because of this, it is thought that operator needs for mechanisms of control on the center system and information gathering will rise.

As described above, while bringing the initiative for smartification of the whole community into view, MHI is assuming the following four related business areas in the EV field.

[1] Vehicle management (Telematics)
[2] Charger management (Charger Sales/Operation Management)
[3] Power resale (Recharger Business)
[4] Power management

In the demonstrations, MHI plans to establish a future business hypothesis, verify the technologies and simultaneously consider and verify services appealing to users and operators during the demonstration period.