Featured Articles

Island Smart Grid Model in Hawaii Incorporating EVs

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OVERVIEW: Having set a target of replacing 40% of its electric power generation capacity with renewable energy by 2030, the state of Hawaii in the USA is proceeding with the installation of wind and PV power generation. To aid this work, a smart grid demonstration project is being conducted on the Hawaiian island of Maui under the leadership of NEDO. The aim of the project is to solve the problem of how to use EVs to stabilize the supply of electric power despite the fluctuating output of renewable energy. Hitachi commenced operation of the EV Energy Control Center for controlling EV charging in December 2013. It is now working on the development of VPPs, with advanced technology for using EVs as a distributed generation system.

INTRODUCTION

AGAINST the background of worsening global environmental problems, trials of smart communities and smart grids are taking place around the world in a variety of forms with the aim of moving to a low-carbon society. One example is the state of Hawaii in the USA, which has set a target of replacing 40% of its electric power generation capacity with renewable energy by 2030, and which is proceeding with the installation of wind and photovoltaic (PV) power generation.

A smart grid demonstration project on the island of Maui in Hawaii (the “JUMPSmartMaui” project, formally titled the “Japan-U.S. Island Grid Project”) is being run jointly by the New Energy and Industrial Technology Development Organization (NEDO), Hitachi, Mizuho Bank, Ltd., and Cyber Defense Institute, Inc. Operation of trial sites commenced in December 2013.

This article gives an overview of the island smart grid model, which uses electric vehicles (EVs) and is one of the parts of the Japan-U.S. Island Grid Project handled by Hitachi, describes some of the results of analyzing the data collected since testing commenced, and looks at technology enhancements that can be expected in the future.

SYSTEM OVERVIEW

The project aims to improve the convenience of using EVs in order to encourage their adoption by installing EV direct-current fast chargers (EV DCFCs), initially at five sites around Maui, and subsequently at an additional 15 sites. The sites were selected based on an analysis of traffic patterns and distances from homes, offices, and tourist sites. To provide the island with an energy infrastructure that does not depend solely on fossil fuels, it will also use the EVs as batteries to absorb excess energy and to stabilize a grid that has a large installed capacity of renewable energy.

Fig. 1 shows an overview of the project.

In addition to installing EV DCFCs, the project will also include systems for the home (standard EV chargers, water heaters, and PV power generation) and large grid batteries.

In particular, the EV Energy Control Center (EVECC) described in this article provides integrated energy management for the island and exchanges information with an integrated distributed management system (DMS) and energy management system (EMS) located in the control room at the Maui Electric. The EMS controls the island-wide balancing of supply and demand on the Maui Electric Company grid.

SYSTEM FUNCTIONS

EV Chargers and EV Charging Management System

EVs require an EV charging management solution that enables multiple vehicles to charge simultaneously and controls charging output to reduce power use.

(1) EV DCFCs

Hitachi supplied variable-output EV DCFCs that were adapted for use on Maui by incorporating a

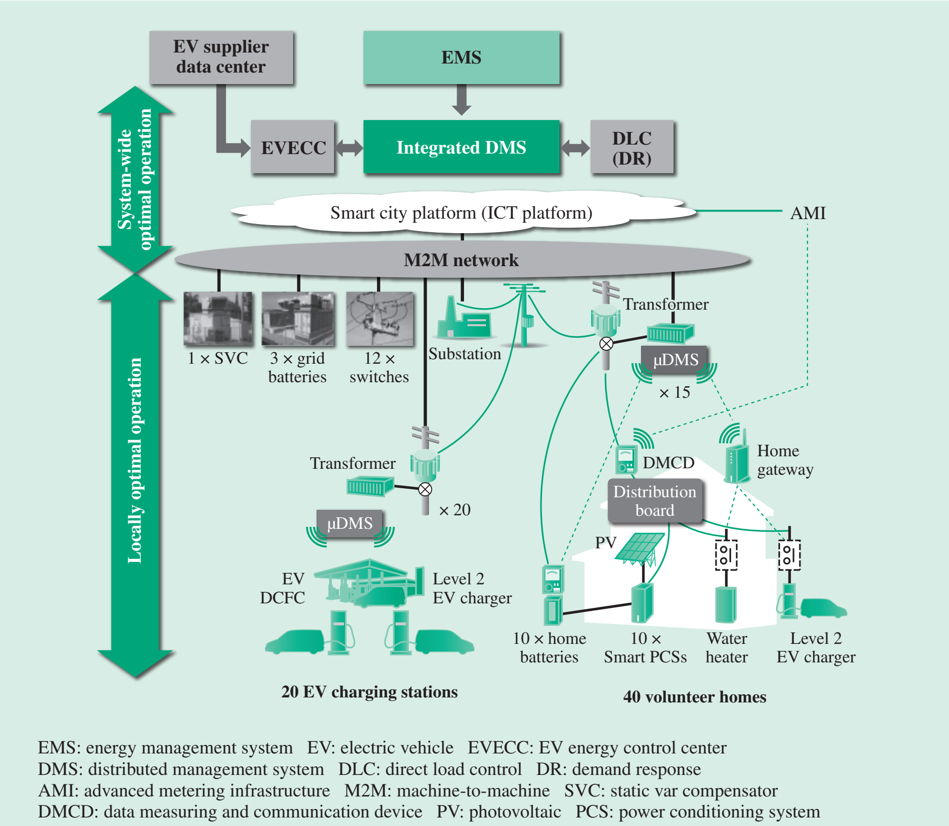

Fig. 1—Overview of Smart Grid Demonstration Project.
In addition to its network of EV DCFCs, the Smart Grid Demonstration Project on the Island of Maui in Hawaii also includes systems for the home and large grid batteries.

direct load control (DLC) function and the ability to be coordinated with existing generation plants. Hitachi also supplied a charging management system that supports the EV DCFCs. The charging management system for Maui uses EV DCFCs that can be expanded from one to four units. A number of EVs can be connected simultaneously. The charging management system allocates a total output capacity of 60 kW between the vehicles, with the precedence for charging being determined by the order in which they were connected. Once the charging of one vehicle is complete, the charging of the next vehicle commences.

Fig. 2 shows a photograph of an EV charging station.

The EV DCFCs at the five sites currently in operation are characterized by the following types of use.

(a) Site A: Located at a large shopping complex at a major center on the island
(b) Site B: Located at a medium-sized shopping center
(c) Site C: Located near a tourist site (aquarium)
(d) Site D: Located near a tourist site (plantation)
(e) Site E: Located at a hotel

To cover a wide area, the EV DCFCs were installed at five sites around Maui, with a further 15 sites planned. The sites were selected based on an analysis of traffic patterns and distances from homes, offices, and tourist sites.

(2) EV charging management system

The charging management system, which performs integrated management of the chargers via a machine-to-machine (M2M) network, has functions to collect information on charger operation and to provide information via web screens to EV users. Information technology (IT) is also used to verify user membership. Users can choose an appropriate time to charge their EV by accessing the web screens to check whether sites are in use or undergoing maintenance.

Fig. 2—EV Charging Station.
EV DCFCs are in use at five sites.

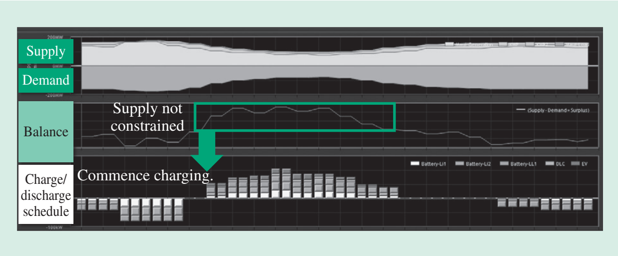

Fig. 3—Load Shifting.
Charging is scheduled to be performed at times when the supply of electric power is not constrained.

EV Energy Management

To put excess energy to good use, the EVECC has a function for scheduling when home chargers commence charging. It acquires information from the integrated DMS about the balance of supply and demand on the grid, and state of charge (SOC) information (how much power remains in the EV batteries) from the EV supplier's data center. It also performs EV energy management by coordinating control of charging with the information from the grid.

Fig. 3 shows an example of load shifting to balance supply and demand for electric power. First the integrated DMS obtains information about the supply and demand for electric power, including renewable energy, from the EMS at the power company's control center, then it uses this to produce a schedule of when excess energy is likely to be available. Next, the integrated DMS and EVECC exchange information about the supply and demand balance and EV charging schedule so that the EVECC can revise this schedule. Finally, the EVECC controls when EV charging starts to utilize the excess energy.

Grid Stabilization

Micro distribution management systems (μDMSs) installed on low-voltage transformers monitor the voltage on the low-voltage grid. When a μDMS detects a fault, such as a voltage rise caused by a reverse power flow from a PV power generation system or overloading caused by several EVs charging at the same time, the initial response to protect the pole-top transformer is to issue reactive power control commands to smart power conditioning systems or to turn off EV charging to avoid voltage deviations.

The integrated DMS monitors fluctuations in the power distribution network caused by the varying output of renewable energy. In this demonstration project, sensors installed on the grid are used to monitor the supply and demand balance on the distribution network. In emergencies, the supply and demand balance is maintained by using the DLC function to disconnect consumer loads such as water heating or EV charging.

In particular, the challenges for the DLC are to disconnect sufficient load to stabilize the grid frequency while avoiding disruption to consumers caused by these disconnections. The constraints are as follows:
(1) Minimize excessive disconnections to maintain supply and demand balance.
(2) Complete control operations within a fixed time to prevent them from continuing for a long time.
(3) Minimize disruption to consumers caused by restricting power demand.

Grid stability is maintained without causing disruptions to consumers by issuing multiple disconnection commands to deal with the uncertainty of their outcomes, and by optimizing the choice of devices to be disconnected so as to complete control operation within a fixed time and to minimize the disruption this causes.

DEMONSTRATION PROJECT

Data on the use of electric power, EV DCFCs, and other systems have been collected since the project commenced in December 2013. This section describes the data collected to date and what it implies about how well the system can be expected to work.

Energy Management

This section describes the results of charging control at the EV charging stations.

Fig. 4 shows an indicative graph of current flow data from the μDMSs installed on the transformer at the site A EV charging station. Fig. 5 shows the EV DCFC usage at the charging station over the same time period.

Fig. 5 shows how heavy use is being made of the EV chargers at those times when Fig. 4 indicates a high load on the transformer secondary. Limiting the EV DCFC output when the transformer becomes overloaded helps with grid stabilization because it provides an adjustment margin that can be used without affecting other loads.

EV Charging Infrastructure

This section presents data on the use of EV charging stations, and what this data indicates about how they will be operated in the future.

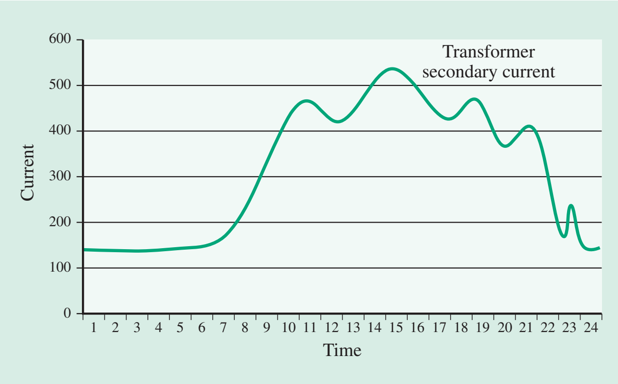

Fig. 4—Data Collected from µDMS.
This graph shows an approximation of the current flow data from the µDMS installed on the transformer at the site A EV charging station.

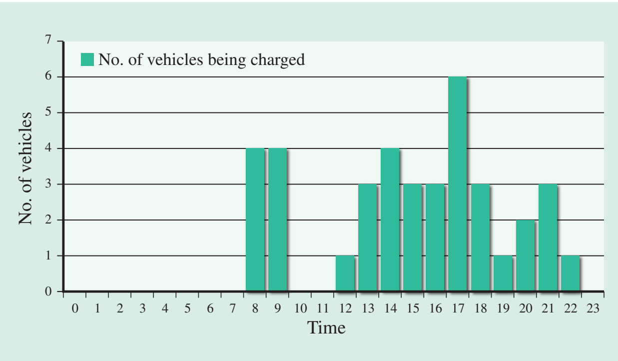

Fig. 5—EV DCFC Use.
The DCFC is heavily used at times of high load on the transformer secondary.

Table 1 lists the number of charges, total power use for charging, and total charging time for the five sites that have already commenced operation. It is assumed that site A has the highest usage because it is located in a public place (a shopping complex) where users can make use of the time taken for charging.

Similarly, Fig. 6 shows a graph of total charger use across all sites at different times of the day. The heaviest use comes in the afternoon (from 3 to 5 PM),

TABLE 1. Actual Use of EV Charging Stations
The highest usage is at site A, which is located at a shopping complex.

Site	No. of uses	Charging power (MWh)	Charging time (min)
A	2,995	22.4	1,203
B	1,780	13.9	656.1
C	304	2.5	90.7
D	330	3.2	97.1
E	285	3.5	108.3

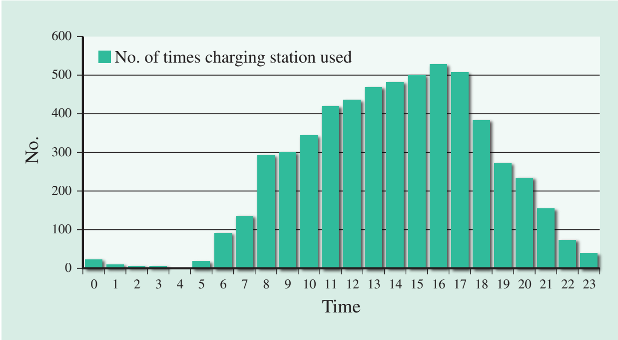

Fig. 6—Charging Station Use at Different Times of Day.
That the most frequent use of the chargers occurs in the afternoon is believed to be influenced by the habits of Maui residents.

which is believed to be because this is the time when many Maui residents are returning home from work.

In the case of Maui, where demand for charging is concentrated at particular locations and times, the EV DCFCs selected for the project help reduce congestion because they are able to charge a number of vehicles at a time, and select the best order in which to start charging each vehicle. Hitachi also plans to monitor the effects of scheduling when to charge EVs at home.

FUTURE TECHNOLOGY ENHANCEMENTS

This section describes virtual power plants (VPPs), a technology for the future.

In the context of this article, a VPP is a group of EVs that can be operated as a power plant, treating the EV batteries as a mobile form of power storage that can be discharged as well as charged. One way this function can be utilized is to charge EVs during the

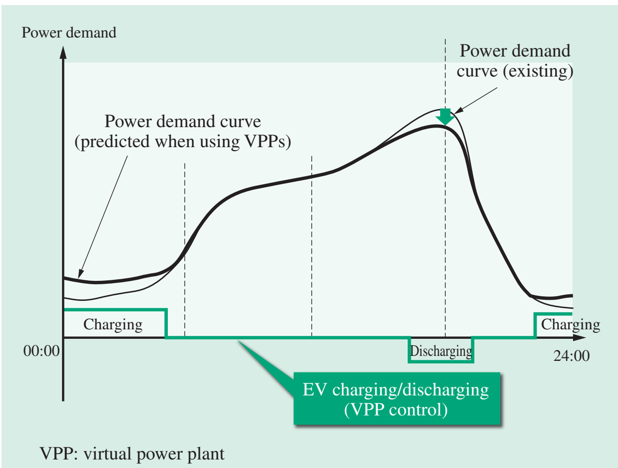

Fig. 7—Power Demand Scenario Using VPPs.
VPPs have the potential to reduce peak power demand.

night, when the level of power generation is low and electricity tariffs are cheap, and to discharge EVs that have returned home for the day at times when power demand is high (especially in the evening). This has the potential benefit of reducing peak demand for electric power (see Fig. 7).

Because this can cut the cost of generation by having the system that manages EVs perform group control of charging and discharging for a number of EVs that are clustered geographically in order to reduce peak demand, it is also potentially of benefit to electric power companies. Since the equipment used in this demonstration project includes EV chargers, systems for the home (standard EV chargers, water heaters, and PV power generation), and large grid batteries, the VPP concept can be applied not only to EVs but also to other consumer equipment.

CONCLUSIONS

This article has described an island smart grid model in Hawaii that uses EVs, and has reviewed data collected from a demonstration project to show how it can be applied to the smart grid model. The article has also described VPPs, a technology that is expected to be developed further in the future.

The demonstration project commenced test operation in December 2013, with evaluation of the benefits of installing the demonstration system scheduled to continue for two years. Hitachi plans to continue reviewing the project and working to improve energy management by analyzing data collected during this time. Hitachi also plans to utilize future technology enhancements in its work on assessing the benefits of smart grid models that use EVs.

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