

Linkage System for Fleet Management and Building Energy Management Using EVs

Tatsuya IDE¹

Kazumasa HONDA¹

Senryu OH¹

Yoshiya NAKAGAWA¹

Takuya TANAKA¹

ABSTRACT

This research targets the social implementation of a system that helps to reduce electric utility costs and CO₂ emissions with low investment by utilizing EVs as storage batteries and performing energy management that efficiently shares electricity between EVs and buildings. This paper introduces a fleet management system, an energy management system, and a battery sharing management system that links these two systems, and presents the effects to help reduce electric utility costs and CO₂ emissions as verified by a proving test.

1. Introduction

At the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), it was agreed to pursue efforts to limit the increase in global average temperature to 1.5°C above pre-industrial levels⁽¹⁾.

The transportation sector accounted for 17.7% of Japan's CO₂ emissions in FY2020⁽²⁾. The introduction of electric vehicles (EVs) is a means of helping to reduce CO₂ emissions, but although EVs are equipped with large-capacity batteries compared to household storage batteries, the energy density is lower than that of gasoline, so in general the cruising distance tends to be shorter. Therefore, to perform at the same level as before while increasing the CO₂ emissions reduction effect, it is necessary to further enhance transport and delivery efficiency by measures such as high-precision estimates of energy needs for travel and route optimization.

In addition, interest in environment, social, and governance (ESG) in management is increasing and environmental management indexes are said to be directly connected to corporate value. RE100 is a global initiative in which companies aim to supply 100% of the electricity used in their businesses through renewable energy^{(3),(4)}. Clean electricity can be generated by installing photovoltaics (PV), one type of renewable energy, on buildings. However, as

this is affected by the weather, management of the generated power is needed for more effective use. An example of this is introduction of PV, stationary storage batteries, and an energy management system (EMS). Storage batteries are expensive, however, so introduction of such batteries capable of storing the amount of electricity generated by PV incurs a large cost burden⁽⁵⁾. It was therefore thought that by using the batteries of EVs, there would be no need to purchase stationary storage batteries, which may reduce the introduction cost burden.

In order to use EVs both for transportation and as storage batteries for buildings, the challenge is not only to optimize operation routes, but also to optimize vehicle dispatch planning, including the power management of on-board batteries.

2. Development Goals

For some time Honda has been developing a Home Energy Management System (HEMS) that uses EVs⁽⁶⁾. HEMS realize the utilization of EVs as home storage batteries by predicting household electricity demand, PV power generation, and the periods during which the EV is at home.

In order to provide similar value as HEMS to businesses, differences in the base electric utility rate setting and the larger number of EVs used compared to ordinary

¹ Innovative Research Excellence Power Unit & Energy
E-mail: tatsuya_01_ide@jp.honda

households make it necessary to address the complexity of managing the use of EVs with destinations that change on a daily basis. A new EMS using EVs based on the Honda-developed HEMS was therefore developed as shown in Fig. 1.

In the electric utility rate plan for businesses, the base rate is set according to peak power⁽⁷⁾, so the goal of this development is a system that minimizes peak power as shown on the left side of Fig. 1.

Next, regarding the increase in the number of EVs, it is necessary to consider the shorter cruising distance of EVs compared to gasoline vehicles and develop a fleet management system that matches the ways each business use EVs, as shown on the right side of Fig. 1.

Furthermore, when linking the EMS and fleet management system and using the EV batteries for peak power shaving, as the number of vehicles and the EV battery capacity are limited, there will be cases when EVs cannot be simultaneously used for both transportation and peak power shaving. To address this issue, it is necessary to develop a function to judge whether to prioritize EV use or peak power shaving as shown in the center of Fig. 1.

The above contents were organized, and the following three functions were developed.

- (1) A fleet management system that efficiently uses multiple EVs
- (2) An EMS with the purpose of helping reduce the base electric utility rate
- (3) A battery sharing management system that enables both the EMS and fleet management systems to work together in a time- and energy-efficient manner

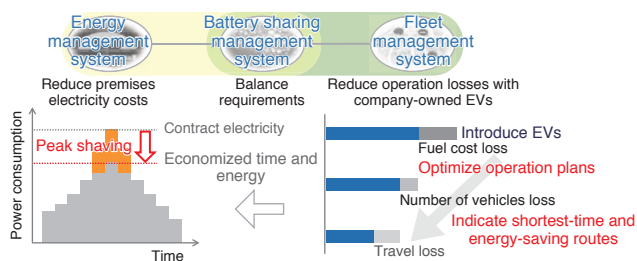


Fig. 1 System schematic and aim

3. Overview of Developed System

Figure 2 shows the function layout of the developed system. The flow from left to right in the figure when the three functions of this system operate is as follows: users enter the times that EVs will be used and the destinations the day prior to use; then the fleet management system calculates the optimal routes to the destinations and the electricity consumption needed to travel those routes.

In parallel, the EMS predicts the building's electricity

demand and PV power generation for the next day, and the purchased electricity prediction results are calculated by subtracting the predicted PV power generation from the building's predicted electricity demand. The battery sharing management system calculates the number of vehicles and the time needed for peak shaving from the building's purchased electricity prediction information predicted by the EMS and the building's target contract electricity. The plan arbitration function then allocates the vehicle plan for peak shaving, adjusts to achieve both use as transportation and use for peak shaving, and completes the creation of a dispatch plan.

On the day, when a user utilizes an EV as transportation, the route with the lowest energy consumption calculated by the fleet management system is displayed on the navigation system, as shown on the right side of Fig. 2. In addition, EVs secured for peak shaving use can help reduce peak power by having the EMS perform charge and discharge control. The details of the fleet management system, EMS, and battery sharing management system are explained in order below.

3.1. Fleet Management System

The fleet management system has the two functions of predicting energy consumption for travel in use as transportation and managing vehicle reservations. Prediction of energy consumption for travel is explained here. Energy consumption prediction determines the route that uses the least energy and takes the shortest time in consideration of traffic and weather information to the destination and calculates the amount of energy needed.

To calculate the amount of energy needed for travel, a physical calculation model was constructed by dividing the model into four components: (a) vehicle-specific running resistance and power train efficiency; (b) a speed model created by linking with the navigation system information; (c) an auxiliary load prediction model; and (d) a regenerative model.

3.2. EMS

The EMS is equipped with three functions: predicting the electricity a building will purchase, and controlling

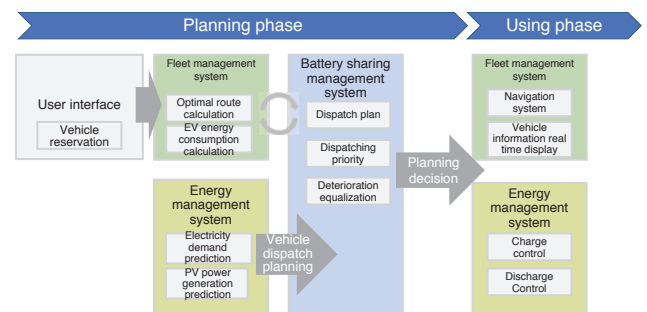


Fig. 2 System function layout

discharge to the building and EV charging on the day. An overview of each function is described below.

(1) Purchased electricity prediction function

It is necessary to dispatch EVs for peak shaving if the purchased electricity is quantitatively predicted to exceed the contract electricity. Particularly in the case of PV power generation, it is necessary to predict not only the amount of power used but also the amount of power generated by PV, and to calculate the purchased electricity as the difference. This system trains prediction models using feature values extracted from past statistical data such as weather information, actual electricity usage, and actual PV power generation as input information. When actually predicting the purchased electricity, a fully trained prediction model is used, and the purchased electricity prediction is calculated by inputting the weather forecast results for the day, as shown in Fig. 3.

(2) Discharge control (peak shaving control)

EVs are parked at the building and connected to charge/discharge stations for peak shaving based on the dispatch plan created by the battery sharing management system. In the EMS, the EVs are charged/discharged based on instructions given by the controller (EMS controller) that controls charging/discharging.

The contract electricity is determined by the peak power value in 30-minute increments, so the EMS controller obtains the power at 1-minute intervals and calculates the average value over a 30-minute period. If this average value exceeds the target contract electricity, the pre-dispatched EVs will discharge.

In addition, to increase the peak shaving success rate, the EMS controller implements discharge control that takes into account the delay in the control response from the time the EMS controller issues an instruction until the charge/discharge station is controlled.

(3) Charge control

The EMS controller controls multiple charge/discharge stations while calculating the 30-minute cumulative electricity demand in order to charge the EVs so that the electricity demand does not exceed the target contract electricity.

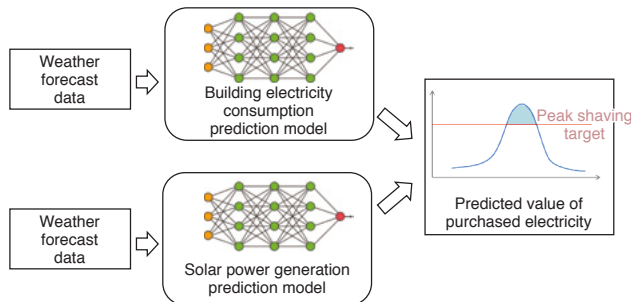


Fig. 3 Model for predicting purchased electricity

3.3. Battery Sharing Management System

Figure 4 shows a schematic of battery sharing management system operation. The upper portion of the figure shows the vehicle reservation status prior to system activation, with users having reserved arbitrary vehicles. The lower portion of the figure shows the vehicle reservation status after applying the peak shaving reservations made by the EMS. The original operation reservations have been assigned to different vehicles, and the plan has been rearranged to realize both the operation reservations and peak shaving reservations. In addition, prioritization has been carried out in consideration of optimization of the dispatch plan according to the reservation conditions, battery deterioration, etc.

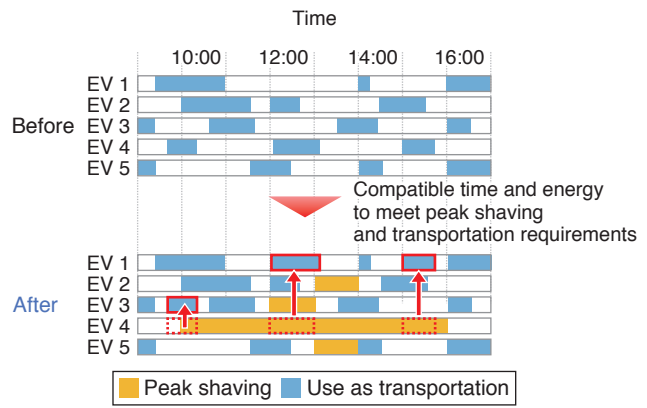


Fig. 4 Battery sharing management system

4. Proving Test

As shown in Fig. 5, a proving test is being conducted as of April 2023 with the cooperation of Suzuhiro Co., Ltd. (hereinafter, “Suzuhiro”) in Odawara City, Kanagawa Prefecture. As part of its environmental activities, Suzuhiro has been working for some time to introduce renewable energy equipment such as PV power generation and to establish buildings that aim to achieve an annual primary energy consumption balance of zero (Zero Energy Building: ZEB)⁽⁸⁾. This proving test began from an alignment of interests of Suzuhiro, which aims to realize carbon neutrality by producing and consuming energy locally, and this research, which targets practical application of energy management utilizing EVs. This proving test is focused on Suzuhiro’s head office building and uses EVs as commercial vehicles in and around Odawara City on a daily basis.

Figure 6 shows an overview of the proving test system. The originally operated five gasoline vehicles and HEVs were replaced with five Honda e EVs, and five charge/discharge stations were installed. A web application for automatically reserving dispatches and a dashboard that

displays the building power and vehicle information were developed as a user interface for the system described in Chapter 3.

Figure 7 shows the operation status of Suzuhiro's gasoline vehicles and HEVs as surveyed prior to the start of the proving test. The solid line represents the median number of EVs in use as transportation at each time, and the blue hatched area represents the range of three times the standard deviation (3σ) over the median number.

The greatest vehicle usage is from around 10:00 to 15:00, and the median number in that time period is two vehicles or less but varies widely. On the other hand, the frequency of using five units as transportation at the same

time was found to be low. From this it was thought that the variation of 3σ can be absorbed by the battery sharing management system and assumed that three vehicles can be used for peak shaving. Taking into consideration the discharge capacity of the charge/discharge stations, a target of 15 kW was set.

From this peak shaving target value, the targets for the whole system were defined as follows.

- Base electric utility rate reduction effect of 20% (20 kW), considering the amount due to cooperative control of peak shaving and air conditioning
- CO₂ emissions reduction effect of 60% by changing to EVs and route optimization



Fig. 5 Suzuhiro office building and EVs used for test

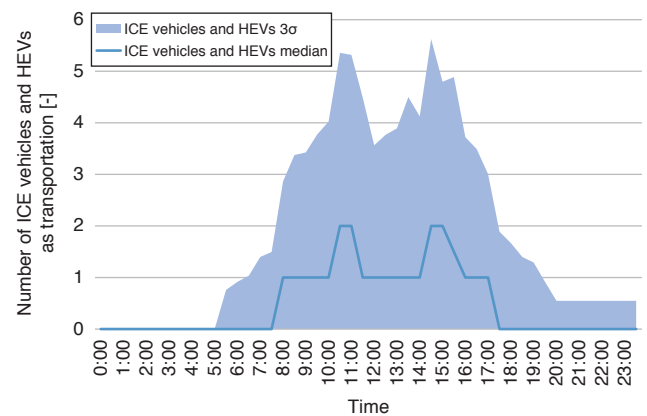


Fig. 7 Operation status of 5 ICE vehicles and HEVs as transportation before start of test

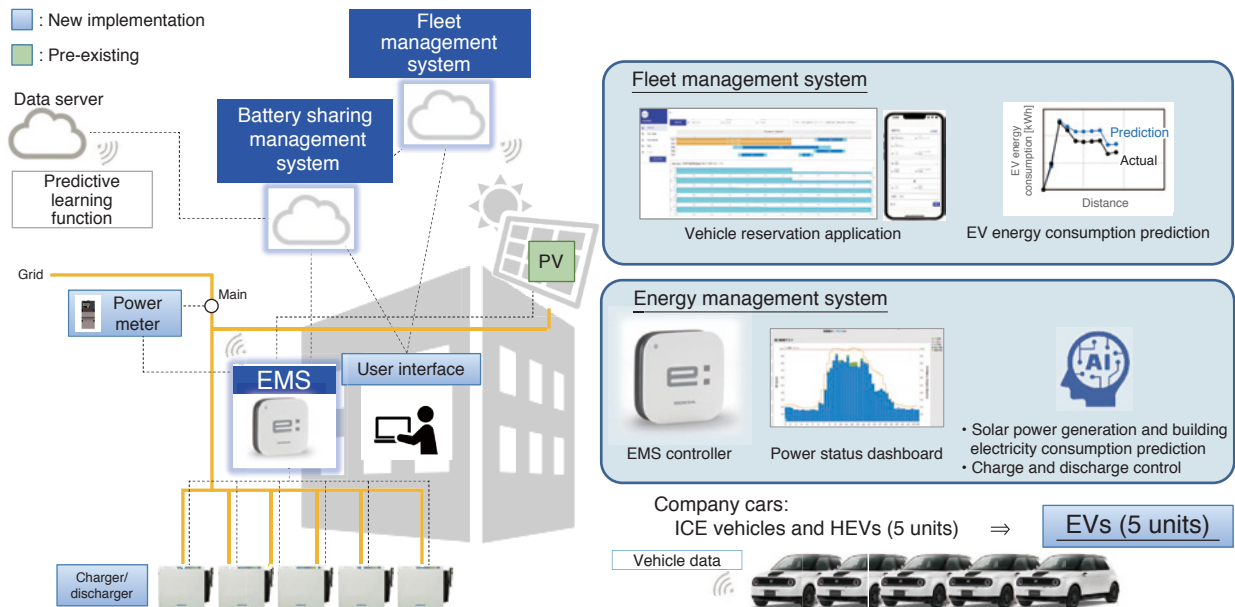


Fig. 6 System configuration of proving test

4.1. System Operation

In order to illustrate the specific effects of the constructed system, Fig. 8 shows the power status of the building for one day as an example. The yellow line is the building's purchased electricity predicted by the EMS. The system calculates the number of vehicles needed for peak shaving in time slots when this predicted electricity exceeds the target contract electricity.

On this particular day, the predicted value of the purchased electricity greatly exceeded the target contract electricity, so it was calculated that three EVs would be needed for peak shaving, especially from 8:00 to 14:00, as shown in the dispatch plan in Fig. 9. On the other hand, there were six reservations for use as transportation, and the battery sharing management system formulated a plan and made reservations for use as transportation and peak shaving. The red frames in Fig. 9 show the time slots in which EVs were actually operated, and it can be seen that the vehicles are used for peak shaving in the planned time slots and as transportation in the time slots reserved for use as transportation.

Figure 8 also shows that power was discharged from the EVs (red bars in the figure) at the time of building power peaks, enabling to keep the actual purchased electricity (blue bars) to the target contract electricity (solid black line) or less.

The above results show that prediction, dispatch planning, and charge/discharge station control operated normally, and the system functioned as expected.

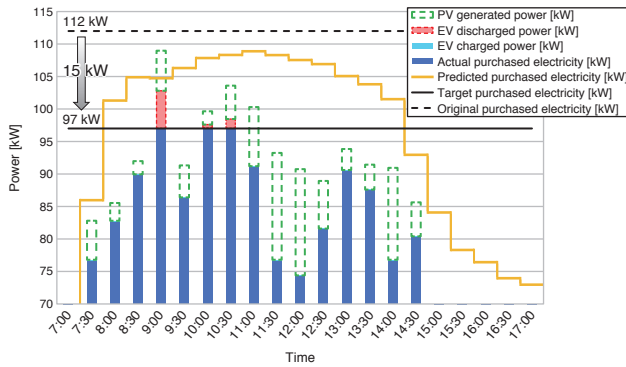


Fig. 8 Office building power status

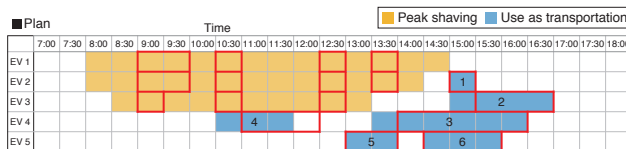


Fig. 9 Vehicle dispatch plan and actual use

4.2. Confirmation of Battery Sharing Management System Effectiveness

Through the introduction of this system, the ability to coordinate five EVs for the two purposes of peak shaving and transportation was evaluated. Figure 10 shows the results for use as transportation throughout the year. The trend is similar to that found when use as transportation was investigated prior to the start of the proving test and shows that there was no substantial change in usage even when vehicles were replaced with EVs. As shown in Fig. 8, the purchased electricity also increases from 8:00 to 14:00, and it is necessary to achieve both applications of peak shaving and transportation during this time period.

Figure 11 shows the results of the highest number of dispatched vehicles per day when only days throughout the year with reservations for peak shaving are extracted. Blue indicates EV reservations for use as transportation, and yellow indicates EV reservations for peak shaving. Red indicates reservations for gasoline vehicle and HEV operation. In 82 of the 84 times during the year that peak shaving reservations were made, the battery sharing

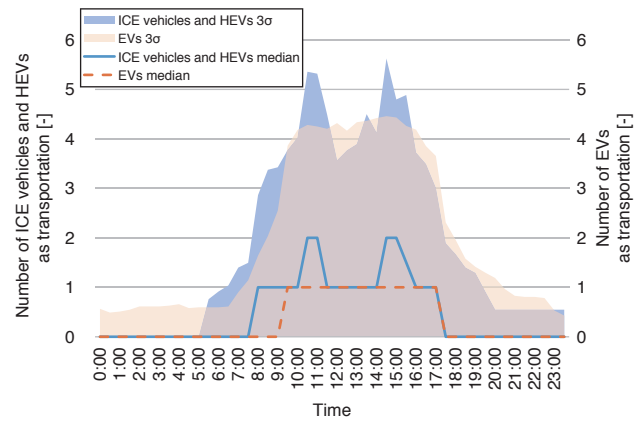


Fig. 10 Operation status of 5 EVs as transportation during test

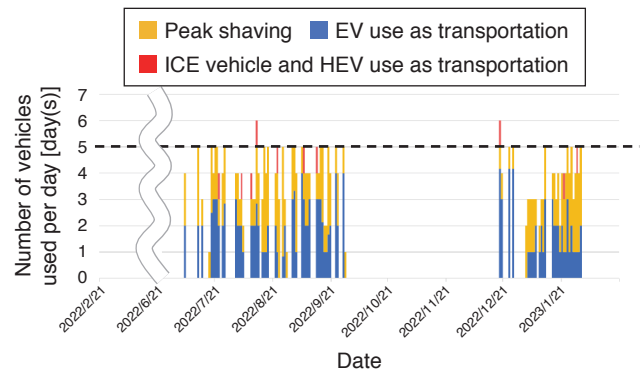


Fig. 11 Highest number of dispatched vehicles per day

management system functioned effectively, enabling achievement of use as transportation as well as peak shaving with five EVs.

4.3. Electric Utility Cost Reduction Effect and CO₂ Emissions Reduction Effect

The effects of the introduction of this system to help reduce electric utility costs and CO₂ emissions were estimated under the following conditions.

- Base electric utility rate unit price: 1,470 [yen/kW]
- Energy price: Gasoline 163 [yen/L], Electricity 20.3 [yen/kWh]
- CO₂ emissions intensity: Gasoline 2.322 [kg/L], Electricity 0.434 [kg/kWh]

Throughout the one-year proving test, peak shaving occurred on five days in the summer and seven days in the winter for a total of 12 days. Of the 12 days when peak shaving occurred, the largest amount reduced by discharge from EVs for a single day was 7.4 kW, and a total of 51.5 kWh was reduced over the 12 days.

Based on this, the introduction of this system reduced base electric utility costs by 20% as shown in Fig. 12, achieving the target of 20%. In addition, replacing gasoline vehicles with EVs and optimizing routes reduced CO₂ emissions by 46%. The reason why the CO₂ emissions reduction target of 60% was not achieved was that, in a certain percentage of cases, a large number of passengers or objects needed to be transported and the test vehicle (Honda e) was not suitable for such tasks, so a reserve gasoline vehicle or HEV was used instead.

Suzuhiro has also estimated that adding control that selectively charges EVs with clean power generated by PV facilities can help reduce CO₂ emissions from company-owned vehicles by 98%.

4.4. Future Initiatives

Approaches going forward include initiatives to increase the accuracy of building electricity predictions, use of real-time building electricity and vehicle data to enhance the linkage between the EMS and fleet management, further

reduction of peak shaving dispatch times, and increase of operating rates.

5. Conclusion

A linkage system for the fleet management system and the energy management system was developed and the following results were achieved in a year-long proving test.

- (1) Through the introduction of this system, it was proved that EVs can be used both as transportation and for building energy management.
- (2) Use of five EVs for peak shaving throughout the year reduced electric utility costs by 20%, and changing to EVs and route optimization reduced CO₂ emissions by 46%.

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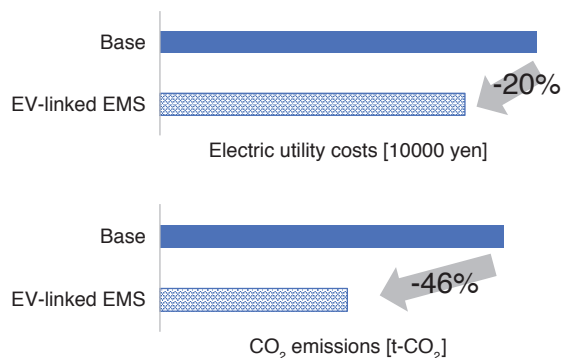


Fig. 12 Electric utility cost reduction effect and CO₂ emissions reduction effect

■ Author ■



Tatsuya IDE



Kazumasa HONDA



Senryu OH



Yoshiya NAKAGAWA



Takuya TANAKA