

Development of Battery Traceability System for EV

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ABSTRACT

The EV market is expected to expand, and as this happens, battery usage will increase. Batteries deteriorate with time and usage, and when battery capacity declines as a result of age-related deterioration, the cruising distance over which a vehicle can travel decreases. Therefore, it will be important mainly to monitor batteries during use but also to assess the performance of batteries during the resale of used cars and during secondary usage such as conversion to stationary batteries. Honda has equipped the FIT EV first leased in the summer of 2012 with a system that regularly sends mainly battery-related data to a server when the vehicle is travelling and when the battery is charging. Customer consent is obtained to collect data from Japan and the U.S. on the Honda R&D Japan server. The goal of this system was to determine battery performance and to build a model for estimating battery deterioration, so that a foundation for successful data analysis and visualization could be built.

1. Introduction

Batteries deteriorate with time and usage (repeated charging and discharging). Deterioration mainly involves the decline of battery capacity and output; however, when the capacity of an EV battery, in particular, declines, the distance that the vehicle powered by the battery can travel decreases. This means that a decline in battery performance causes a decline in vehicle performance⁽¹⁾. Therefore, the ability to accurately assess battery status is considered to be necessary for vehicle operation, the used-car market, and secondary use, and this ability is expected to be an important factor for developing services capable of responding to market needs in the future EV market (Fig. 1).

The battery traceability system for EVs that Honda developed is provided with a mechanism for collecting mainly battery-related data from individual vehicles that are travelling or charging and regularly sending the data to a server. In other words, battery-related data from all vehicles that are leased is aggregated on this system, and traceability data (hereinafter, “trace data”) is gathered. This trace data is important for determining the status of the battery and the status of the vehicle. The data is analyzed in real time and needs to be effectively utilized in developing batteries and expanding business and services.

Methods of collecting and analyzing massive quantities of data that are known as “big data” (large data size, multiple data sources, unstructured data, high-volume transactions) are additionally being proposed. To utilize big data is to rapidly and in real time process data that has been collected

thus far but has not yet been fully analyzed, as well as data that took time to analyze and process. Such data processing enables information from massive quantities of data to be visualized, analyzed, extracted, and then utilized in business and services. Big data utilization is gaining attention as a means of swiftly responding to and establishing action plans to address changing values and a changing market in which various products continue to be made electronic. Trace data can also be thought of as a part of big data.

Based on the background described above, a system foundation was built to analyze and visualize gathered trace data in order to determine battery performance in EVs and create a model for estimating battery deterioration.

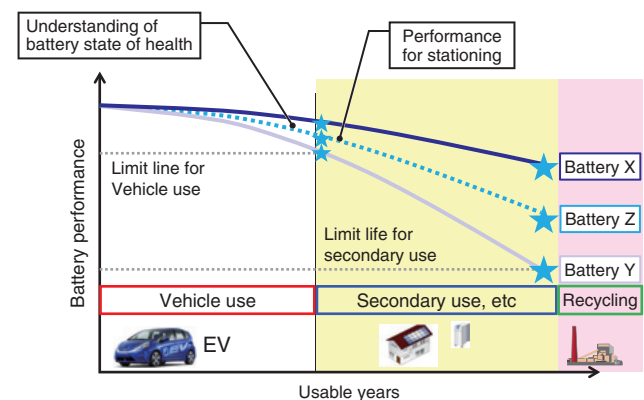


Fig. 1 Importance of battery performance understanding (EV)

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2. System Configuration

2.1. Concept

The usage status of a battery is influenced by changes in traffic and differences in battery charging equipment. In order to observe differences in battery information resulting from differences in the travelling region and battery usage status, it is believed that data should be collected and analyzed in one place. Therefore, after data is collected from various regions, Honda aggregates the data on the Honda Japan R&D internal server via an internal intranet and then consecutively analyzes that data.

2.2. Vehicle System

The FIT EV, which is the vehicle in which the traceability function has been installed, possesses a telematics communication unit that uses a smartphone application to enable the air conditioning timer to be operated, charging to be controlled, and the status of charging to be determined. The battery traceability system consists of this system foundation and a data collection function (Fig. 2).

Vehicle information sent by the telematics communication unit (TCU) is received and collected in real time on the regional server using pre-existing equipment for communication-type vehicle navigation systems. In this system, an intranet is utilized in communicating between central servers, and sent vehicle information is compressed into files of binary data on the TCU and data is periodically uploaded (Fig. 3).

Data is sent from the vehicle, especially when the vehicle is travelling, but also when it is charging.

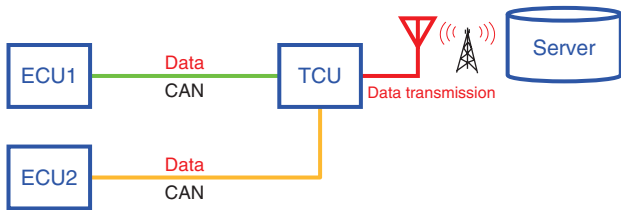


Fig. 2 Vehicle system composition

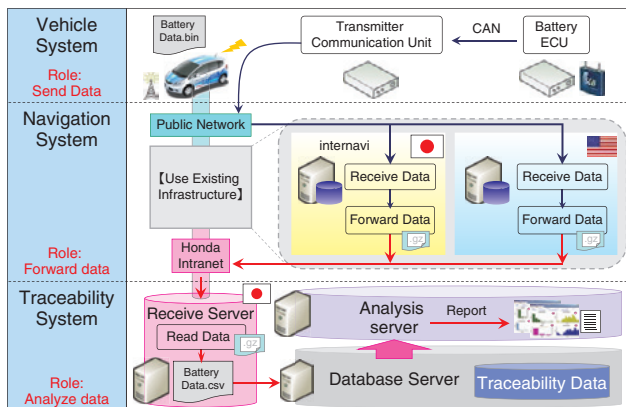


Fig. 3 Transmitting system configuration

2.3. Server System

The battery traceability server is configured with blade server architecture and a virtual platform. Web service technology (SOAP over HTTP) is used in communicating between the battery traceability server and the vehicle navigator server, the data is received on a reception server and received binary data is turned into text and accumulated into a database for analysis.

3. Building a Model for Estimating Battery Deterioration

Batteries differ greatly in capacity retention (capacity maintenance rate) depending on their history, such as the duration of use, temperature, and state of charge (SOC). In addition, previous research has shown that even batteries with the same capacity maintenance rate can develop differences in remaining battery life if their history differs (Fig. 4)⁽²⁾.

3.1. Conventional Method of Estimating Battery Life

The capacity maintenance rate that is generally used to estimate battery life is expressed by Eq. (1), which is proportional to the square root of time (root principle). When using this equation, it is impossible to express differences in the rate of battery capacity decline resulting from differences in usage history. The reason is that, in the root principle equation, the change rate of the capacity retention rate: differential equation of Eq. (1) is represented by Eq. (2) and the usage conditions and the capacity retention rate at that time are expressed. Therefore, as Fig. 4 shows, if batteries with the same capacity retention rate but different histories are later used in the same way, the later capacity retention rate will be mistakenly deemed the same. Thus, this equation cannot be used to perform an estimate that accounts for the deterioration rate of individual batteries.

$$y = 1 - a \times t^{0.5} \quad (1)$$

$$y' = -\frac{0.5}{1-y} a^2 \quad (2)$$

y : Capacity retention rate

y' : Change rate of the capacity retention rate

a : Deterioration factor decided by the usage conditions

t : Integrated usage time

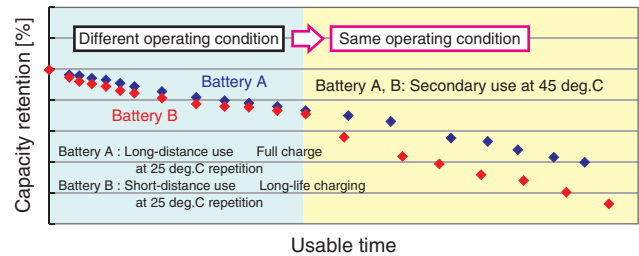


Fig. 4 Capacity retention variation by specification operating condition

3.2. Battery Life Estimation Method that Accounts for Usage History

By including the past battery usage history in the estimation equation, it is believed to be possible to represent differences that result from usage history. If factors that influence future deterioration can be uncovered from the past usage history, then it is possible to index the remaining value of battery during use, in the used vehicle market, and in secondary use, as shown in Fig. 1. It is also expected to be possible to index categorization criteria when remanufacturing battery modules or cells that must be investigated from the standpoint of efficient resource usage. Battery life estimation methods that incorporate usage history are shown in Eqs. (3) and (4).

$$y' = -\frac{0.5}{1-y} (\alpha + b \times \beta) \quad (3)$$

$$y = 1 + \sum_{t=0}^T y' \quad (4)$$

b : Correction factor determined by previous usage history

α, β : Deterioration factor decided by usage conditions

T : Time elapsed since battery production date

Equation (3) shows the deterioration factor a^2 from Eq. (2) substituted by the first-order equation $(\alpha + b \times \beta)$, which incorporates correction factor b that is determined by usage history. It is possible to express the difference in the deterioration rate caused by usage history and, as Eq. (4) shows, the integral of Eq. 3 can be used to estimate the decline of the capacity retention rate. For the usage history, traceability data that was collected by the traceability system is used to derive correction factor b . Because the value of correction factor b differs according to usage history, deterioration rate y' also differs according to usage history. This method allows the capacity retention rate to be estimated even for batteries with different usage histories.

3.3. Verification Results for the New Battery Life Estimation Method

A single-cell battery was used to derive the first order equation coefficient $(\alpha + b \times \beta)$ in above-mentioned Eqs. (3) and (4) from battery property data obtained through shelf tests, cycle tests, and other parameter studies of general battery properties, and a method of estimating battery life was built. The states in which the vehicle was charging, travelling, or parked were all considered when the accuracy of this estimation equation was verified through endurance tests that simulated the actual device load. The measured battery capacity value and the estimated value derived from the battery life estimation method were plotted and compared. The change over time in the values of both plots was nearly equivalent (Fig. 5 and Fig. 6).

In addition, batteries installed in test vehicles were also

verified. The actual value and expected value of the battery capacity retention rate when endurance and driving tests were conducted in extremely hot regions were plotted and compared. Because the change in capacity over time was proximate to the change in actual values over time, as was the case with the single-cell battery tests, the accuracy of the estimation method has been demonstrated (Fig. 7).

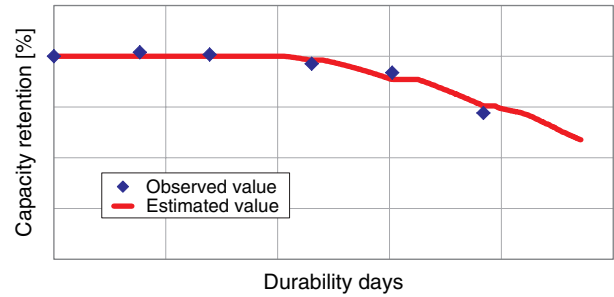


Fig. 5 Normal 200 V charge SOC limit 100% at 55 deg. C

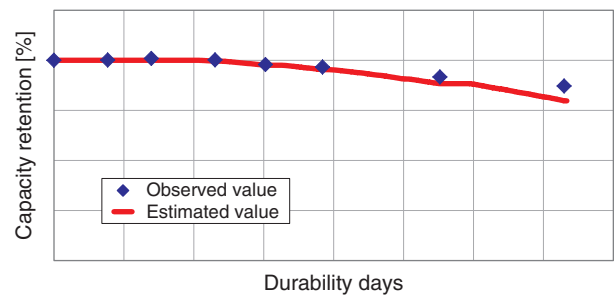


Fig. 6 Quick DC charge SOC limit 100% at 55 deg. C

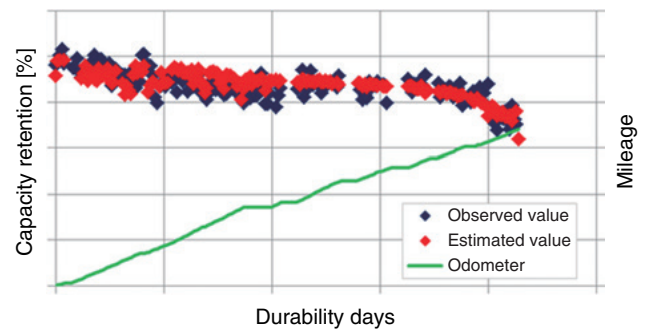


Fig. 7 Verification of life estimation method

4. Analytical Verification of Demonstration Test Data

Collaborative demonstration tests are being conducted by Kumamoto Prefecture, Saitama Prefecture, and Saitama City in order to identify and respond to issues facing the thorough dissemination of the EV and in order to verify future personal mobility and the CO₂ reduction effect under actual traffic conditions or with equipment such as chargers.

Starting in December 2011, vehicles equipped with this system were actually used for demonstration tests, and test driving by local government officials and general users was started. Honda is currently conducting region-specific demonstration tests including park and ride, car sharing, and ride sharing (Fig. 8)⁽³⁾.

The operation of this system began with these demonstration tests, and various criteria have been verified.

4.1. Creating a Data Analysis and Visualization Function

This system is a report system that automatically analyzes and visualizes trace data from vehicles without human intervention. It works by performing pre-set processes, analyses, and extraction processing to enable results to be displayed on a Web browser.

4.2. Trace Data Analysis and Visualization Processing

The trace data analysis and visualization processing in this system can be broadly divided into the following two categories.

- (1) Processing aimed at determining the present battery performance and vehicle status

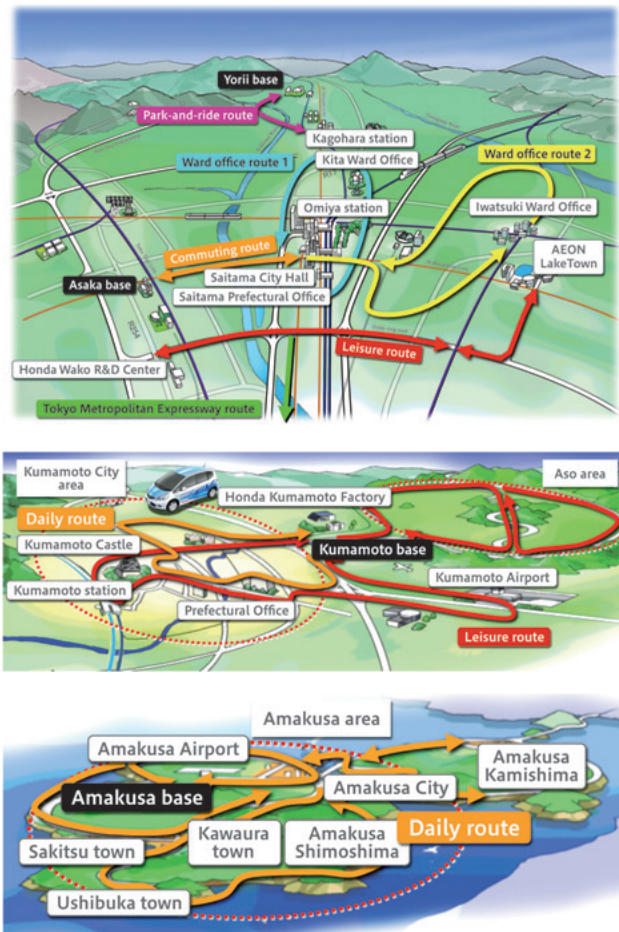


Fig. 8 Honda electric vehicle demonstration program operation area

- (2) Statistical processing that incorporates past travelling data and other data for each vehicle (battery)

For (1), a report system (cockpit) was built that processes data sent from a vehicle in real time, analyzes the present travelling mode such as travelling, charging, or parked, extracts the vehicle status, cumulative driving information summaries, as well as the battery capacity transition, and visualizes battery problem detection, etc. A cockpit report that was developed based on vehicle data for demonstration tests is shown below [Fig. 9(a) and Fig. 9(b)].

The cockpit system displays the total cumulative travelling distance of vehicles in the demonstration tests, histograms of the battery temperature, SOC, battery current, etc., and comparisons with the averages of other vehicles. As a result, changes in the test vehicles can be easily determined.

For (2), an analytical report system was built in which various categories of trace data sent from vehicles are used as indexes, and various analytical reports were developed, including finite and non-finite reports that identify factors arising from battery performance assessments and battery deterioration analyses [Fig. 10(a) and Fig. 10(b)]. In Fig. 10(a), vehicles are continually operated, and the fact that the total distance travelled has exceeded 7700 km in approximately 9 months of operation can be determined in real time. Also, in Fig. 10(b), it is possible to determine

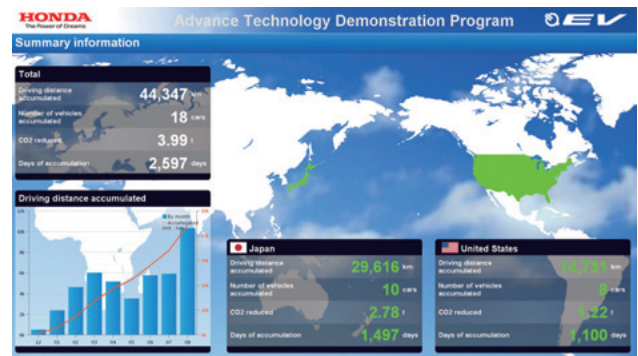


Fig. 9(a) Cockpit report: Vehicle information summary



Fig. 9(b) Cockpit report: Battery state information

differences in how each vehicle was used, and by analyzing the distance travelled in one day, it is clear that vehicle A travels longer distances per day than vehicle B.

Building a report system requires a scalable report system foundation capable of easily selecting factors influencing or possibly influencing battery performance and visualizing and extracting analytical information. Honda's system uses the IBM software IBM Cognos® and IBM SPSS® Modeler to achieve the above-mentioned analytical report system. This software not only enables many types of analyses and reports of various data in an online graphical user interface (GUI), but also allows statistical model analyses to be performed.

4.3. Utilizing the Results of Data Analysis

As for the data analytical system that was developed, Honda is developing and verifying a model for estimating battery deterioration by utilizing the analytical results of data sent from demonstration test vehicles and test vehicles. In addition, the data analysis results can be utilized in many ways; for example, by collecting and analyzing trace data in real time, it is possible to consecutively analyze the status of the battery in the travelling vehicle. As a result, not only is it possible to address mechanical problems, it is also possible to monitor progress after addressing those problems. A specific example is the fact that it is possible to use vehicle data for early detection when battery cell

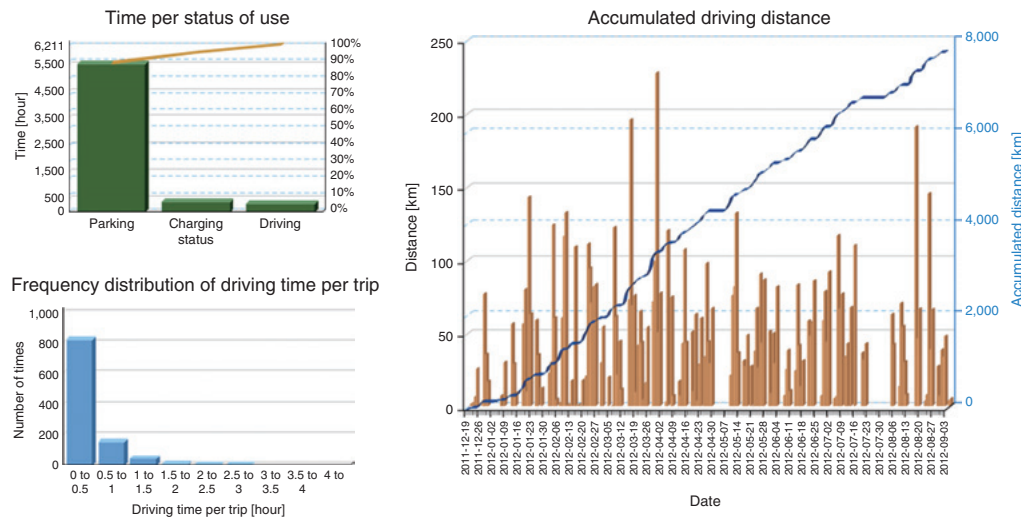


Fig. 10(a) Analysis report total mileage and operation state

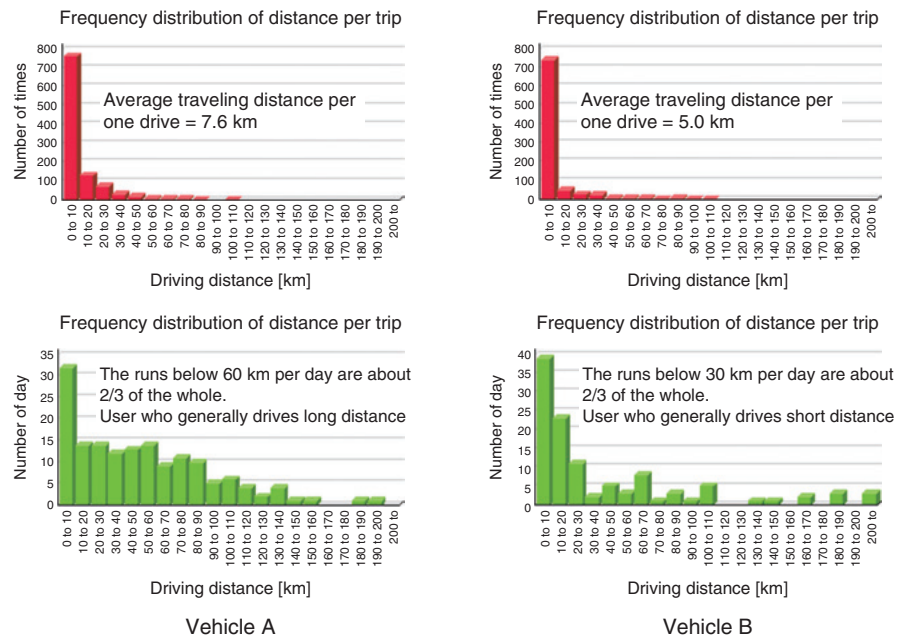


Fig. 10(b) Analysis report distribution of distance

voltage varies more than expected. Considering this, the test vehicle's control unit program was changed to reflect the content of countermeasures for addressing problems. Similar to progress monitoring, it is possible to confirm the change in voltage over time, and thus, the validity of the results of the countermeasure program can be confirmed (Fig. 11).

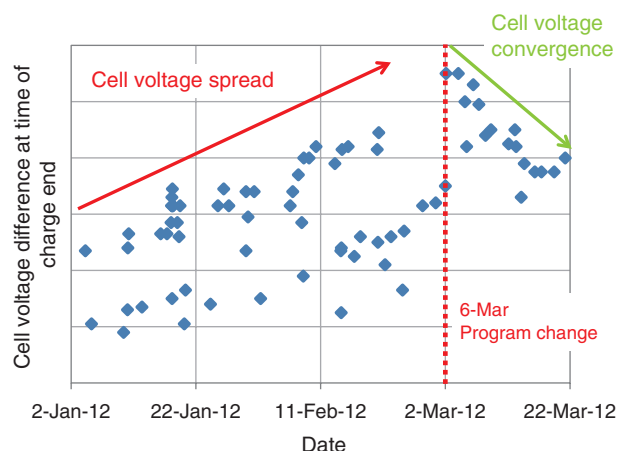


Fig. 11 Early detection and correspondence of vehicle condition

5. Conclusion and Future Outlook

The present vehicle status and battery status were determined by analyzing and visualizing trace data sent from vehicles. Problematic events could also be identified prior to mechanical problems actually occurring by visualizing past data and statistical data. In addition, an expandable trace data analysis foundation was established, which is capable of not only making the above-mentioned determinations but also extracting anomalous data points and implementing specific measures to address problems. Furthermore, by incorporating a battery deterioration assessment capability in addition to a data analysis capability, in the future it will be possible to detect and discover warning signs of capacity reduction, etc. from the battery status.

The initial leasing of the FIT EV to customers in the U.S. began in July 2012. Honda plans to statistically accumulate and analyze trace data collected at the data center with the owner's consent, utilize that data in future development efforts, and investigate control that accounts for differences in battery performance and promote the development of new services.

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