Summary
The major issues in realizing more widespread use of EV are the nuisance of charging the vehicles and their limited driving distance. Honda has developed an EV able to be charged during operation and low-cost infrastructure able to supply power to the vehicle during operation. In terms of the effect of electromagnetic waves, the power supplied to the vehicle and the charge stored by the vehicle, this is a conductive side-type system. Because of this, a conductive side-type system was judged to offer merits from the perspective of safety. Operating tests of the system have already been conducted with a power supply of 450 kW at 150 km/h and above.

1 Research Questions
The development and market introduction of electric vehicles (EVs) is proceeding rapidly as a means of addressing the issue of global warming in our mobile society. However, EVs still present major issues. The driving distance of the vehicles, charging, securing resources for use in onboard batteries, the scrapping of batteries, and a decline in dynamic performance due to increased vehicle weight can all be indicated as the main issues of EVs.

Two main methods can be considered in order to address these issues. One approach is to increase battery performance, or increase the capacity of the batteries employed in the vehicles. The other is to employ ERS, charging of the battery while the vehicle is in motion, as shown in Fig. 1.

Figure 1: High-power ERS
The issues associated with increasing the capacity of the batteries employed in the vehicles include securing resources, attempting to help ensure an adequate production volume, measures for the scrapping of the batteries, a proportional increase in charging time with the increase in the energy capacity of the
batteries, and measures to respond to the heat generated when charging with a high power level. In addition, the fact that vehicle weight increases with increased battery capacity, making it challenging to extend the driving distance of the vehicle, represents a major issue.

The goal of our research is promotion of substitution of internal combustion engine vehicles and realization of carbon free society by ERS (Fig. 2).

![Figure 2: Goals of Research](image)

In the case of dynamic charging, it is necessary that the energy supplied to the battery while the vehicle is in operation should at least exceed the drive energy of the vehicle. In addition, dynamic charging of large vehicles sharing the road with passenger vehicles would necessitate the supply of high levels of power, in the range of 450 kW. Against this background, the research discussed in this paper is proceeding with the development of a ERS that will help realize an unlimited driving distance for EVs by supplying the vehicle with a high power level during vehicle operation.

This report will discuss the results of a study of future infrastructure installation methods and vehicle specifications using simulations with ERS conditions in relation to normal vehicle operation (standard EV operation) when the vehicle is dynamically charged at a high power level of 450 kW (DC 750 V, 600 A), and the results of actual dynamic charging vehicle tests, using a charging power of 450 kW and conducted at a vehicle speed of 150 km/h, in addition to considering the future outlook for the system.

If the system were introduced to expressways, the supply of 450kW of power would represent a ratio of vehicle cruising range to charging lane length of 19:1. This would mean that the restrictions on EV cruising range could be removed by the installation of approximately three kilometers of charging lane per 52km (Fig. 3).

![Figure 3: EV cruising range and running time](image)
2 Methodology\cite{4}-\cite{7}

Figure 4 shows an overview of the ERS. The system is composed of low-cost infrastructure and a dynamic-charging EV. The infrastructure is made up of high-capacity storage batteries and a ERS lane. In the vehicle itself, the system consists of a power collection arm, a dynamic charger, an instantaneous-charging battery pack, and the standard EV system.

![ERS infrastructure and vehicle diagram](image)

**Figure 4: ERS infrastructure and vehicle**

Figure 5 shows a control block diagram for the ERS. The high-capacity storage battery supplies DC power to the ERS lane, and the ERS lane supplies DC power to the vehicle.

![ERS control block diagram](image)

**Figure 5: Control block diagram of ERS**

Figure 6 shows the power collection mechanism. The ERS lane features trolley wires installed on the existing guard rail; positive and negative trolley wires mounted on insulators are arranged in a V configuration. The trolley wires are surrounded by a protective cover of insulating plastic. The height of the power collection arm is centered simply by pushing against the trolley wires arranged in a V configuration from the side, and the roller contacts the power supply mechanism at the correct position.
Figure 6: Power collection mechanism

Table 1 and Figure 7 show the specifications of the ERS. The maximum output of the infrastructure described here is 480 kW (DC 800 V, 600 A), the power received by the vehicle is 450 kW (DC 750 V, 600 A). The vehicle's maximum speed is 150 km or more.

Table 1: Specifications of ERS

<table>
<thead>
<tr>
<th>Item</th>
<th>Type-0</th>
<th>Type-1</th>
<th>Type-2</th>
<th>Type-3</th>
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<tr>
<td>Dynamic charging power</td>
<td>100 kW</td>
<td>100 kW</td>
<td>180 kW</td>
<td>450 kW</td>
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<tr>
<td>Power supply voltage</td>
<td>DC 375 V</td>
<td>DC 375 V</td>
<td>DC 600 V</td>
<td>DC 750 V</td>
</tr>
<tr>
<td>Power supply current</td>
<td>300 A</td>
<td>300 A</td>
<td>300 A</td>
<td>600 A</td>
</tr>
<tr>
<td>Power Transmission distance</td>
<td>0.8 - 1.3 m</td>
<td>0.8 - 1.3 m</td>
<td>0.1 - 1.3 m</td>
<td>0.1 - 1.3 m</td>
</tr>
<tr>
<td>Max. dynamic charging vehicle speed</td>
<td>20 km/h</td>
<td>70 km/h</td>
<td>155 km/h</td>
<td>150 km/h (Final target 200 km/h)</td>
</tr>
</tbody>
</table>

Figure 7: ERS EVs

3 Results (Results of Actual Vehicle Tests of ERS)

Figure 7(d) shows the ERS EVs. The prototype vehicle was manufactured and ERS tests were conducted. The results will be discussed here.
With regard to the output of the infrastructure and the energy received by the vehicle, the system employed a DC voltage of 800 V, a current of 600 A, and a power of 450 kW; the converter employed in the vehicle output a total DC voltage of 750 V, a total current of 600 A to the drive motor and battery.

### 3.1. Results of Actual Middle-speed Vehicle Test

This section will discuss the results of a test of ERS using a target vehicle speed of 60 km/h (Fig. 8(a)).

Figure 8(b) shows that the infrastructure output voltage was controlled, and on the vehicle side the dynamic charge converter target control voltage (750 V) was realized, and input voltage and output voltage were controlled. Figure 8(c) shows that the vehicle-side dynamic charge converter target current during the application of constant current control (600 A) was realized, and input current and output current were controlled. Figure 8(d) shows that the vehicle-side dynamic charge converter target power during the application of constant power control (375 kW) was realized, and input power and output power were controlled. The results shown in Fig. 8 demonstrate that voltage, current, and power were all controlled in accordance with control commands.

(a) Dynamic charging vehicle speed

(b) Dynamic charging voltage

(c) Dynamic charging current
3.2. Results of Actual High-speed Vehicle Test

This section will discuss the results of a test of ERS using a target vehicle speed of 150 km/h (Fig. 9(a)).

As Fig. 9(a) shows, the vehicle entered the ERS lane at a speed of 75 km/h, and, as the drive power to the motor increased, accelerated to a speed of 150 km/h while charging the battery. The results shown in Fig. 9 demonstrate that voltage, current, and power were all controlled in accordance with control commands, while control was applied to absorb the effects of instantaneous deviation from the vehicle’s course.

(d) Dynamic charging power

Figure 8: Results of middle-speed dynamic charging test

(a) Dynamic charging vehicle speed

(b) Dynamic charging voltage

(c) Dynamic charging current
(d) Dynamic charging power

*Figure 9: Results of high-speed dynamic charging test*

**References**


**Authors**

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He is experienced project leader for EV, Modular car body, Chassis, and Formula 1 technology.

He joined Honda R&D in 2001, starting as project leader for the development of “High-power platform vehicles”, then of “Twin Lever Steering systems”.

He then became assistant project leader for the development of “Honda’s racing project” (Formula 1 chassis development which won the world champion in 2009 by the later Brown GP).

He is currently project leader in ERS from 2010.

Prior to joining Honda R&D, he lectured on mechatronics at Japanese university from 2000 to 2001, and prior to this worked for Nissan from 1991 to 2000.