

Further Evolution Towards a New Generation of Electric Vehicles i-MiEV

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Abstract

As part of the new generation of electric vehicles, production of i-MiEV was announced on June 5, 2009, and sales began from July 23. This paper introduces the conditions of random testing through world deployment during this past year, developments in the area of electric vehicles, and also discusses the future direction of evolution.

Keywords

electric vehicle, battery, zero-emission, quietness, life-style

1. INTRODUCTION

On June 5, 2009, which was the World Environment Day, Mitsubishi Motors Corporation announced the production of a model for the new generation of electric vehicles, "i-MiEV", and from July 23, sales began mainly to corporations, government agencies and local government. Sales in the fiscal year 2009 achieved only around 1,400 units, however, a number of awards were received in Japan and from overseas. A summary of customer feedback showed that acceleration and quietness were most appreciated. On the other hand, as a negative evaluation, the characteristics of an electric vehicle were highlighted, for example, a short battery charge range, lack of charging stations, and the dangers of silent driving.

The history of electric vehicles seems new but actually it is old. The first electric vehicle appeared around 1890, which was several years earlier than gasoline vehicles. However, after that, the gasoline vehicle became popular and forced the electric vehicle into decline. Also, Mitsubishi Motors Corporation started development of electric vehicles from the late 1960's, and recommenced development twice again in the 1970's and 1990's, however, it was unsuccessful.

The reason behind renewed development of electric vehicles worldwide is connected to concerns about the sudden depletion of oil resources since late 2000 and also warnings against global warming. At the same time, advanced lithium-ion batteries and advanced miniaturization technologies for permanent magnet synchronous motors, used for electric vehicles, are key components and, therefore, provide the possibility of increased usefulness as a vehicle. In other words, there is a feature of synchronization between environmental issues and technology innovation.

2. PRODUCT FEATURES OF I-MIEV

2.1 Zero CO₂ emissions

"i-MiEV" is a zero emissions car which does not generate CO₂ emissions while driving. The well to wheel (total process of fuel production, supply, and driving vehicle) of CO₂ emissions during power generation is about 1/3 compared to an "i-gasoline" car with a turbo engine (Estimate is based on an average power per unit in Japan).

2.2 100 % electricity power

The cost of running is only for 100 % electricity. The rate plants of electric power company can save money by charging at night.

2.3 Quiet and comfortable driving

2.3.1 Quietness

Electric vehicles are not equipped with engine noise and also vibration sources are minimal so driving is quiet. In addition, quietness has been further achieved by improvements on motor noise, noise-driven system, and road-noise. The interior noise when driving steadily (60 km/h) is the same class as "Galant Fortis", and acceleration achieves even more quietness. Also, the noise emitted was lower than "i-gasoline", approximately 2 dB (A) when at full throttle acceleration from 50 km/h.

2.3.2 Acceleration/driving characteristics

"i-MiEV"'s responses are excellent and it utilizes the characteristics of a high-torque electric motor from slow speed and achieves more powerful driving than "i-gasoline" with a turbo engine. And also, because there is no shift shock and engine vibration, driving has a smooth sense of acceleration and running.

2.4 Enough mileage for daily use

One charge was realized as 160 km on the 10.15 mode (The examination by MLIT). The actual mileage is

affected by the condition of operating air conditioner and driving patterns, however, the “i-MiEV” has achieved a cruising range which is enough for everyday use as a light vehicle. According to a questionnaire survey of drivers in Japan, the average driving mileage for one day on a weekday was about 90 % less than 40 km. Also, even on a holiday, it was 80 % less than 60 km. By adapting the display feature for battery fuel gauge and possible cruising distance on the meter panel, ease of driving is supported.

2.5 3-way charging system

There are three methods of charging batteries for driving: normal chargers of AC100 V and AC200 V, and fast charging at a battery charge station. The normal charge connector from a regular outlet is on the right side of the vehicle, and the charge connector from the fast charger is on the left side. Table 1 shows the relationship of charging time between various pure electric systems and “i-MiEV”. Figure 1 shows a photograph.

Table 1 Charging time

Method (Charge amount)	Source	Time *
Quick charging (80 % charge)	3-phase 200 V 50 kW	Approx. 30 min
Normal charging (full charge)	200 V (15 A)	Approx. 7 h
	100 V (15 A)	Approx. 14 h

Note: Charging can take longer when air temperature and line voltage are low.



Fig. 1 Photograph of i-MiEV

3. TECHNICAL FEATURES OF I-MIEV

3.1 Packaging

“i-MiEV” is equipped with battery packs instead of a large fuel tank under the floor which makes effective utilization of the “rear-midship layout” of “i-gasoline”. The motor, transmission, inverter, and the charger were equipped to take the place of engine and transmission. These key components are all placed under the floor, so, it was able to isolate the high volt-

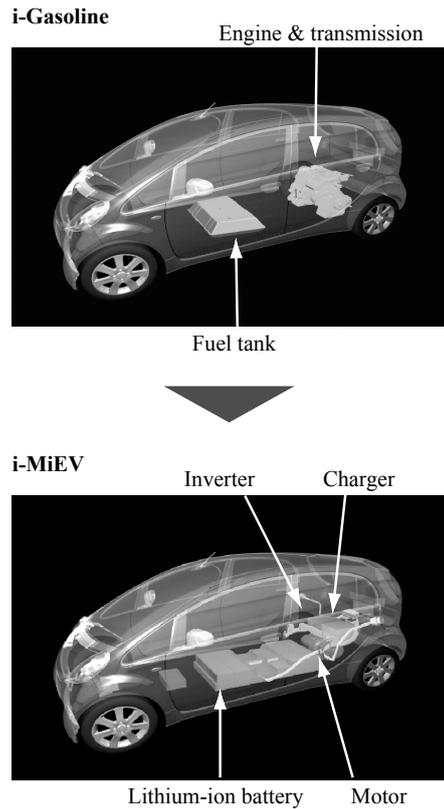


Fig. 2 Differences of “i-gasoline” and “i-MiEV”

age wires from the interior space. And also, because the equipped driving battery is mounted under the floor, the center of gravity of the vehicle became lower, therefore, enabling good running. Also, there is no change of the interior space and capacity for four adults, therefore, “i-MiEV” has the advantages of “i-gasoline”. Figure 2 shows the difference of “i-gasoline” and “i-MiEV”.

3.2 Key components

Figure 3 shows the configuration of the “i-MiEV” system.

3.2.1 Battery for driving

The battery for driving of “i-MiEV” adopted large-capacity lithium-ion batteries for electric vehicles made by Lithium Energy Japan (LEJ). The battery for driving is constructed of a total capacity of 88 cells in series configuration (total power 16 kWh) which is connected to 4 or 8 battery cells each of 3.7 V/50 Ah with series connections. This battery for driving is used for driving the motor, the power supply for air conditioning systems, and auxiliary battery charging.

3.2.2 Battery technology for driving safety

A multi-safety strong structure protects the battery for driving, and also protects the battery pack, the frame around it, and the battery cells.

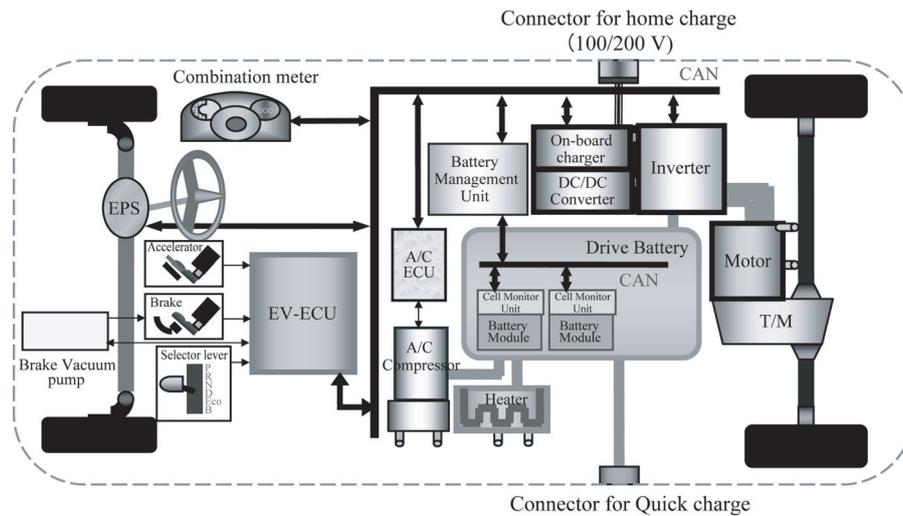


Fig. 3 i-MiEV system

(1) Battery cell

As for the cell, it adopts excellent safety materials and internal structure, using high stable special cathode materials, and they are housed in a sturdy case as shown in Figure 4.



Cell

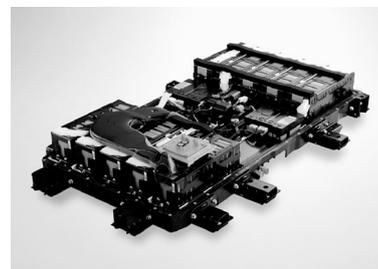


Module

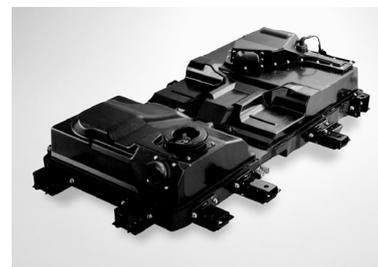
Fig. 4 Photograph of battery cell and module

(2) High rigidity battery pack

Fiberglass resin was used for the driving battery pack. Rigid structure was adopted by inserting modeled sheet metal plates in the case, and made highly waterproof, protecting the battery inside. The entire system, including the high-voltage battery pack, is on the platform floor and placed inside the body frame. And also, there is protection from the double cross frame and under cover, therefore, it is possible to reduce the damage by a multi-directional crash and projection from the



Battery for driving



Battery package

Fig. 5 Photographs of the housing and battery

road (See Figure 5).

3.3 Established battery company

On December 12, 2007, Mitsubishi Motors established “Lithium Energy Japan (LEJ)” which is a joint investment company with GS Yuasa Corporation and Mitsubishi Corporation for the development and manufacture of large sized lithium-ion batteries as a part of the commercialization of electric vehicles. Also, in April, 2010, they announced a plan for a fourth plant in Shiga Prefecture. After establishing the fourth plant, the total production capacity became 600 million cells. 67,800 units will be converted to “i-MiEV”, a total investment of 517 billion yen.

3.4 Permanent magnet synchronous electric motor

The motor adopts a permanent magnet synchronous electric motor which is smaller, lighter, and has higher efficiency because of using neodymium magnets with rare earth and optimization of winding. The permanent magnet synchronous electric motor is a motor that appeared in the mid-1990s. By using a neodymium magnet, which has a larger magnetic force compared to a ferrite magnet, the strongest magnets have been used, so performance can be achieved from a small motor. Also, it is suitable for equipment to electric vehicles and greatly improves the power performance. "i-MiEV" motor's maximum speed is 8,500 rpm, and the maximum output is 47 kW (3,000-6,000 rpm) which is the same as "i-gasoline" with a turbo engine. This motor has the specific characteristic of generating high torque from low revs, and the maximum torque is 180 N•m. Such a compact and lightweight motor was developed and the performance shows higher power than a turbo engine. Figure 6 shows a photograph of the motor.



Fig. 6 Motor (Type Y4F1)

3.5 Integrated control techniques appropriate to the new generation of electric vehicles

The "i-MiEV" Operating System consolidates information for all EV components, "i-MiEV" to integrated

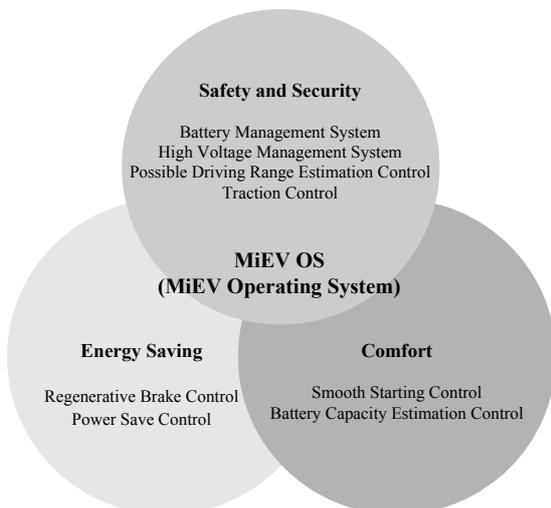


Fig. 7 MiEV OS (MiEV Operating System)

control. Permanent monitoring and battery status, energy recovery by regenerative braking capability, and powerful, smooth launch control are carried out by highly integrated control technology, and comfortable driving is achieved while providing safe and reliable energy. Figure 7 shows a description of the "i-MiEV" Operating System.

4. FLEET TESTING

Tests were conducted on "i-MiEV" throughout the world. Testing was performed in U.S.A., Europe and Asia. The total mileage traveled abroad reaches more than 500,000 km. Also, testing in New Zealand and Australia and several other countries is still in progress.

5. CHADEMO (CHADEMO) ASSOCIATION

The Chademo Association was established in March 2010, and its aim is for technical exchange and the development of a fast charger. The secretary companies are Tokyo Electric Power, Toyota, Nissan, Subaru, and Mitsubishi. At the time of foundation, there were 158 members, and by August 1, 2010, the number increased to more than 280. The feature of the Chademo system is the usability of various electric vehicles. Before the charge, the status of charging protocols for communication is checked, then, it transmits instructions from the vehicle, and DC current is sent. In other words, according to the state of the electric vehicle, this charging system can choose several types of charge.

6. EVOLUTION FOR ELECTRIC VEHICLES

There are many business models of electric vehicle. Currently, there is a possibility of utilizing a smart grid for various applications. At the Tokyo Motor Show 2009, Mitsubishi Motors proposed an electric vehicle which can even be put into the living room because of zero emissions. A similar concept has also been conducted at the Akasaka Housing Gallery by Mitsubishi Estate Home. There are many benefits in being able to put an electric vehicle into the living room. As examples, it is convenient for getting in and out, no effects by summer and winter temperatures, it is not necessary to charge at night outside in the dark, and charge operation is easy when raining. Regarding these points, not only architects of houses, but also designers of shopping centers and hospitals are very interested.

In the future, the spread of electric vehicles is expected to change lifestyles, therefore, there should be proposals for a variety of offers to the customer.

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