AC/DC Hybrid Air Conditioner

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ABSTRACT
The novel AC/DC hybrid air conditioner is powered either through AC power line or directly through a rechargeable battery while a conventional air conditioner is designed to operate only on AC power. A conventional air conditioner needs a DC-to-AC inverter, the conversion of power from DC to AC to be connected with a battery. Therefore it increases a loss of power. The AC/DC hybrid air conditioner is capable of battery-powered operation without the DC-to-AC inverter, has achieved high efficiency.

Keywords: DC, Air Conditioner, HEMS, ZEH, AC/DC Hybrid Air Conditioner

INTRODUCTION
In 2013, the Japanese cabinet approved an energy policy that will make it a goal for all newly-constructed public buildings to be zero-energy by 2020.

A Zero Energy House (ZEH) is a house that consumes less energy than it produces on a net annual basis by creating renewable energy, usually through photovoltaic cells installed on the roof. ZEHs do at times consume non-renewable energy and produce greenhouse gases, but at other times reduce energy consumption and greenhouse gas production elsewhere by the same amount.

ZEHs are equipped with solar panels and batteries, which store electricity generated in the daytime. Home appliances, including air conditioner and refrigerator, consume less energy. Home Energy Management System (HEMS) allows residents to control their air conditioners and energy use with an integrated controller. The HEMS also enables residents to monitor and visualize their energy consumption and savings.

Under the FIT (Feed-In Tariff), renewable electricity generators, including homeowners, business owners are paid a cost-based price for the renewable energy they supply to the grid. However, the price they can expect ranges and is uncertain in the long-term contracts because the FITs often include "tariff digression". Considering the FITs and ZEHs, it would be more suitable for homeowners and business owners to utilize the renewable energy on their own rather than selling it to the grid.

We have a high performance battery, a high efficiency air conditioner and HEMS technology, and have connected them together to help residents to achieve ZEH because the air conditioner consumes a lot of energy, about 25% of total energy consumption in house. Therefore we have developed the AC/DC hybrid air conditioner which can be directly connected to a battery to utilize DC power without a DC-to-AC inverter, improving energy efficiency by about 5% compared to a conventional air conditioner with a DC-to-AC inverter.

NEW-PRODUCT DEVELOPMENT
A JOINT DEVELOPMENT AMONG MULTIPLE BUSINESS UNITS
The photovoltaic cells, batteries, air conditioners and HEMS we develop are normally designed for those products' specific markets. However, the AC/DC hybrid air conditioner has been produced in close liaison with multiple business units, especially the battery and HEMS to maximize the product performance as a consolidated system.

MARKET DEMAND
Newly-constructed houses will be equipped with the HEMS, which controls the amount of energy consumption in home appliances, and the direction of power flow for ZEH. A battery is a key component, stores electricity from solar panels at times. The size of the battery will be optimized, adapting to the balance of storage and usage. Needless to say, home appliances must operate more efficiently in ZEHs.

PRODUCT CONCEPTS
We have focused on improving the efficiency of the system, a high-efficiency air conditioner has connected with a battery. The battery power supply is DC power whereas the air conditioner runs only on AC power. The power conditioner is generally used between them to convert DC power to AC power, where the certain amount of energy is lost in the conversion process. An
air conditioner requires AC power, however inside the air conditioner, AC power is converted to

![Air Conditioner operates using DC electricity directly from the PV](image)

DC power, which means DC power should be connected to the internal circuit of an air conditioner to eliminate multiple conversion losses such as DC-to-AC in a power conditioner and AC-to-DC in an air conditioner.

Fig.1 shows the product concept. The AC-DC hybrid air conditioner we have developed can utilize DC power directly from the battery.

**PRODUCT DEVELOPMENT**

1. High efficiency and comfort using DC power effectively
2. Comply with various safety regulations

Generally, the DC voltage in an air conditioner is controlled about 280[V], which is rectified and smoothed from the AC input voltage. However, the DC voltage to ground in house wiring must be under 150[V] following the Japanese regulation, JEAC 8001-2011. To comply with this regulation, we have developed the new PFC to control the DC voltage, accumulating the both incoming AC power and DC power.

We also have developed "Cloud HEMS", which automatically switches back and forth between AC power and DC power, considering the charge status of the battery and the amount of power generation from the solar panel. The air conditioner is aligned with the JET(Japan Electrical Safety & Environment Technology Laboratories) certification, where safety is secured in the new specific evaluation for the AC/DC hybrid air conditioner.

**ORGANIZATIONAL STRUCTURE AND MANAGEMENT**

Working groups have been formed consisting of representatives from Sales, Marketing, and Engineering Division to produce the system in close liaison with cloud HEMS, solar panel, battery, and air conditioner. Table 1 shows the organizational structure and management. The R&D departments are also included in the development to conduct numerous experiments, and discuss the feature of the system.

**FEATURES OF TECHNOLOGIES**

AC/DC HYBRID AIR CONDITIONER

**PRODUCT OVERVIEW**

A conventional air conditioner uses AC power from a power conditioner, where the DC power from the battery is converted into AC power. However the conversion process increases the power loss. On the other hand, the AC/DC hybrid air conditioner in Fig. 2 is able to connect directly with the battery without the power conditioner, which means the power loss through

![Product Overview](image)

Table 1  Organizational Structure and Management

<table>
<thead>
<tr>
<th>Products</th>
<th>Working Groups</th>
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<tbody>
<tr>
<td>Air Conditioner</td>
<td>Air Conditioning systems Business Unit</td>
</tr>
<tr>
<td>Cloud Battery</td>
<td>Energy solution systems Business Unit</td>
</tr>
<tr>
<td>Cloud HEMS</td>
<td>Cloud systems Business Unit</td>
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![Electrical Block Diagram of AC/DC Hybrid Air Conditioner](image)

the conversion is reduced. The cloud HEMS controls which power supply should be used, AC power or DC power monitoring the status of the battery, the amount of power generation from the solar panel, and time. As a result, it makes the air conditioner more stable and reliable.
Fig. 3 shows the electrical block diagram of AC/DC hybrid air conditioner. The outdoor unit of the air conditioner is connected with the battery, which supplies the DC power at 100[V] to ground in house. The PFC in the outdoor unit increases the DC 100[V] up to DC 280[V] to run the compressor motor and the fan motor efficiently. The relay for the DC power is activated after the relay for the switch of AC power supply and DC power supply is activated to secure the greater safety. The conversion loss in the power conditioner has been reduced.

Fig. 4 shows the AC/DC hybrid air conditioner with cloud HEMS. There is a special-purpose command for interfacing between the air conditioner and the HEMS controller, managing the battery status, the amount of power generation from the solar panel, and time. The air conditioner decides suitable power source after the command is sent from the HEMS controller. For the high-power operation, the air conditioner operates on AC power. For the low power operation, the air conditioner operates on DC power. The air conditioner operates only on AC power when the cloud HEMS decides to suspend DC power due to the lack of the battery amount.

FEATURES OF THE PRODUCT
We have achieved a 5% reduction in the conversion loss connecting directly with the battery (Fig. 5). The automatic switch between AC power and DC power enables the air conditioner to improve efficiency and comfort and to maintain stability (Fig. 6). The inside unit of the air conditioner indicates which power source is applied, AC power or DC power. The customer easily recognizes the status of the power source with the indicator (Fig. 7). The application for smart phone shows the status of the HEMS. The audio equipment of the air conditioner announces the condition of the system for customers to be notified of high efficient operation.

CONCLUSION
Fig. 8 shows a comparison of the annual power consumption. We have achieved a 5% reduction in the conversion loss connecting air conditioner directly with the battery. The annual power consumption has been reduced to 1,233[kWh] from 1,270[kWh]. The APF (Annual Performance Factor) has been improved by 3.1% compared to the conventional one. The annual power consumption of air conditioner in Fig. 9 has been always on downward trend. However, the rate is sluggish recently, 1.2% from 2004 to 2014. Considering the current trend, it is significant for our product to successfully reduce a 3.1% in the annual power consumption.
Fig. 8  Comparison of the Annual Power Consumption

Fig. 9  Trend of Annual Power Consumption of Air Conditioner