# Household Energy Storage System featuring Efficient Power Management and Environmental Compatibility

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**Abstract**

NEC is marketing a lithium-ion battery-based household energy storage system capable of the automatic control of power consumption in households. Based on extensive use of NEC's energy storage, control and cabinet technologies, it is an energy storage system for houses that is capable of efficient interconnection with grid and solar-generated power sources. This paper gives an outline of this energy storage system and describes the individual technologies that are used.

**Keywords**

energy storage system, lithium-ion battery, solar power generation
power conditioner, BMS

## 1. Introduction

The recent rise in the need for energy-saving in Japan has resulted in a reduction in electricity consumption and a peak shift campaign for reducing power usage in the daytime peak hours as well as a massive introduction of solar power generation systems for households. In parallel with this trend, there remains the need to maintain household power sources even during a disaster or company power outage. To meet these needs, we are marketing a household electrical energy storage system that connects our proprietary lithium-ion battery technology with its featured safety and long lifespan with a power control technology based on ICT ( **Photo** ).


Photo Household energy storage system (ESS-H-002006A).

## 2. Outline of the Household Energy Storage System

In the summer of 2011 we began to market a lithium-ion battery-based household energy storage system capable of the automatic control of household power consumption thereby making it available for use by enterprises that included housing appliance manufacturers.

Our household energy storage system not only stores nighttime power but it is an energy storage system that enables houses to interconnect efficiently with the grid or a solar power system. The active use of nighttime power can reduce electricity charges and also promote environmental compatibility by reducing energy usage and $CO_2$ emissions. It can also serve as a backup power source for use in the case of a power outage. The present energy storage system has the following features.

- **Feature 1: Active use of nighttime power for saving electricity charges**
  Interconnection with the grid makes it possible to utilize the electrical energy stored off peak in order to satisfy demand during the daytime peak hours.
  This procedure contributes to peak time economy over the entire grid and also reduces the cost of electricity due to the difference in electricity prices between daytime and nighttime.

- **Feature 2: Possibility of interconnection with solar power systems to promote environmental friendliness and electricity saving**
  Interconnection with an existing solar power generation panel makes it possible to store excess electricity in a storage battery according to the amount of solar power generation and the usage of home appliances in each household. Efficient control via such an energy storage system enables reductions both of power consumption and $CO_2$ emissions.
- **Feature 3: Applicability as an emergency power supply, substantial support**
  In the case of a company power outage, the system functions as an emergency power supply by automatically discharging electricity through the distributor panel to back up the power consumed in the household. When a communication module is included in the system, its operation/usage situation can be relayed to the manager so that the system can be supported by remote management.
- **Feature 4: Cabinet design that withstands various installation environments**
  The system is water-proof and dust-proof thereby ensuring normal operation even during a long period of outdoor installation. In addition, anti-rust, anti-salt and anti-bug countermeasures are also taken to deal effectively with various installation environments.

## 3. Configuration of Energy Storage System

The energy storage system is composed of a storage battery for storing electricity, a power conditioner (PCS) for DC-AC conversion of the battery power and a system controller that controls the above components and enables interconnection with both grid and solar power systems ( **Fig. 1** ).

### 3.1 Storage Battery and BMS

To provide users with the benefits of a household energy storage system safely and over long periods, we have developed secondary battery cells featuring high safety and a long lifespan. We also offer a high-functionality battery management system (BMS) for status monitoring and control of the entire storage battery system, including the secondary battery cells.

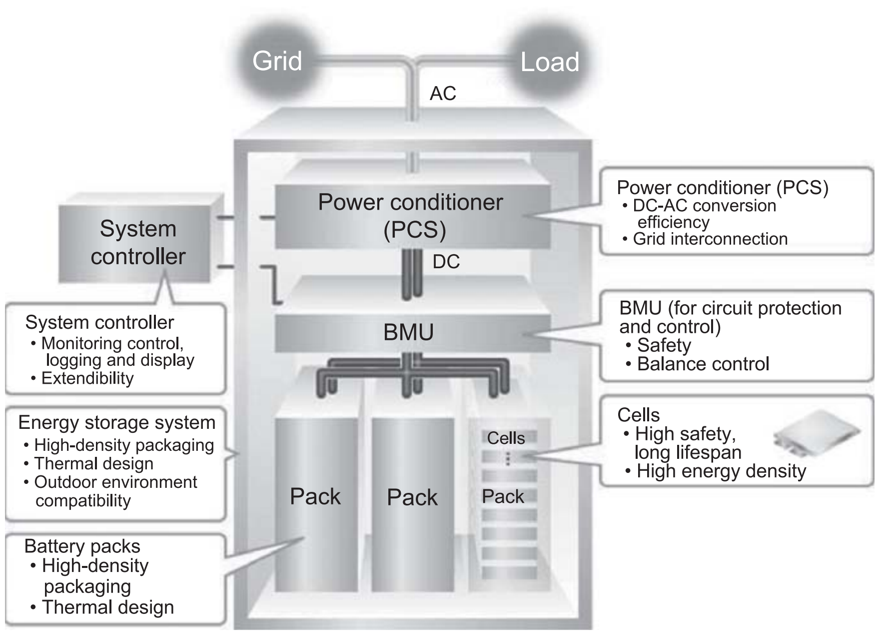


Fig. 1 Components of energy storage system.

**(1) Secondary battery cells featuring high safety and long life**

NEC has been developing lithium-ion secondary batteries since the early 1990's. In 1996 we succeeded in the world-first mass-production of lithium-ion secondary battery cells with manganese positive electrodes. They also featured the spinel structure that does not become unstable even when overcharging occurs. In 2000 we developed the laminated type lithium secondary battery featuring quick charge and high-power discharge capabilities that had been difficult to implement previously. More recently in 2010, we started commercially based mass-production of secondary battery cells featuring high safety and long lifespan for use in environmentally friendly vehicles. These cells utilized the manganese positive electrode and laminated battery technologies that had by that time been in development for more than a decade. The secondary battery cell technologies developed to meet the high-safety and long-lifespan requirements of environmentally friendly vehicles are applied to the household energy storage system.

**(2) Battery management system (BMS)**

In order to ensure safety, the lithium-ion secondary battery cells require circuitry for controlling the charge/discharge of the cells by preventing overcharging, over-discharging, over-current and short-circuiting, which is called the "protection circuit." The present household energy storage system is equipped with a function called the BMS, which protects the safety and ensures the reliability of the cells.

The BMS has the following main functions.

- **Secondary battery cell control:**
  The monitoring of secondary battery cell voltages, etc., for the prevention of overcharge, over-discharge, over-current, short-circuiting, and abnormal outages.
- **Optimum output control:**
  Grid interconnection and independent operation modes.
- **Visualization:**
  System status displays such as for remaining battery capacities.
- **Communication/control interface**
  Information sharing with higher-level systems such as the PCS and HEMS, plus control from the higher level.
- **System maintenance:**
  Remote operation function and transmission of data such as fault information.

### 3.2 System Controller

The system controller controls the operation of the entire energy storage system.

**(1) Software**

The system controller software includes: the "system manager" that manages the operation modes of the energy storage system, the "PCS manager" that manages the power conditioner status, the "LIB manager" that manages the lithium-ion battery status, the "PV manager", "grid manager" and "load manager" that manage other power conditions, the "CAN communicator" that communicates with the power conditioner, the "RS485 communicator" that communicates with the battery and various power meters, and the "information transmitter" that outputs the maintenance information to an external server ( **Fig. 2** ). The status information of the operational mode is shown on the display screen ( **Fig. 3** ).

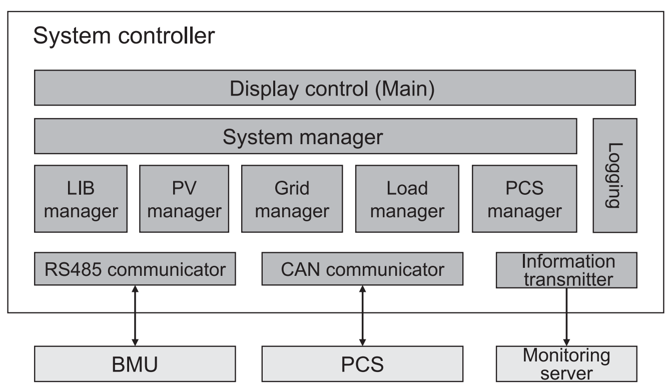


Fig. 2 Software configuration of system controller.


Fig. 3 Example of the system controller display.

**(2) Operational mode management of energy storage system**

The operational modes supported in the normal operation of the newly developed energy storage system can be classified roughly into four modes.

The main function of the system controller is to manage the following operations modes based on communication of information with the power conditioner and storage batteries and the results of measurements of the output power of the solar power generation system.

**1) Power load tracking operation mode**

In this mode, the storage battery is charged from the nighttime power and is then discharged in daytime to reduce the amount of the daytime peak electric power usage.

**2) Power peak cut off operation mode**

The battery charging condition in this mode is identical to the power load tracking operation mode. However, the battery is discharged when the daytime electricity consumption exceeds the contracted power of the daytime grid usage.

**3) Planned operation mode**

The battery charging condition in this mode is identical to the power load tracking operation mode. In the daytime peak, a power cut operation is performed for a certain period, after which the same operation as for the power load tracking operation mode is initiated.

**4) Manual operation mode**

The battery charges and discharges electricity at any time, according to the user control.

All of the operation modes above include the “economy mode” for selling excess solar power to the power company and the “green mode” for charging the storage batteries with the excess solar power.

### 3.3 Cabinet

The cabinet of the household energy storage system is installed outdoors. It is required to offer rugged, hermetically sealed features that allow the internal lithium-ion batteries, precision equipment and network equipment to be installed and operated safely. In the present development, therefore, the key theme was set to deal with various environmental conditions by waterproofing, etc. and also to incorporate quietness as a function in consideration of user convenience. In the following, we discuss the water proofing and noise reduction measures as the most desired environmental specifications.

**(1) Water proofing**

The environmental specifications adopted for the systems cabinets are those that are also used for the radio communication equipment and telephone base stations that we have long been marketing inside as well as outside Japan.

With regard to the water proofing, which is the most representative specification, the present system does not adopt the simple rainproof rating (IPX4) that is applied generally to outdoor fixed equipment but selects the JIS C0920 IPX6 rating, with which no harmful water penetration is produced by strong water jets from any direction.

To meet this rating, the double construction of sunshade + main body and the maze structure of the opening area are built into the cabinet as water-resistant structures. In addition, to secure reliability by covering any possible variance between individual products, 100% of the shipped products are subjected to water resistance inspections.

Thanks to the measures above, the cabinet of the newly developed household energy management system has acquired equivalent reliability to the similar cabinets of the infrastructure equipment.

**(2) Noise reduction measures**

Next, aiming at reducing the environmental load on the living environment, we set the noise specification to type A of the environmental noise standards codes (The area exclusively used for housing: No more than 45 dB at nighttime).

Nevertheless, the household energy storage system had an issue accompanying the efficient use of low-priced nighttime power. This was the activation of internal equipment at night and the resulting operation of the fans for cooling the equipment.

We solved this problem and minimized the fan noise by abandoning equipment cooling using fans to introduce outside air. Instead, we adopted internal air circulating fans and a large-sized radiator for natural air-cooling and succeeded in eliminating the leakage of fan noise through the outside air inlet ( **Fig. 4** ). In addition, we also added a fan rotation control function by installing temperature sensors on the internal air circulating fans so that they are activated only for the minimum required period.

As described above, the cabinets of the newly developed household energy storage systems meet the functional requirements for safe installation and operation

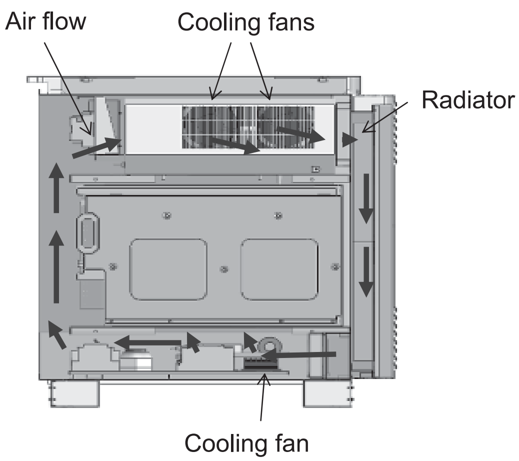


Fig. 4 Cooling System Construction

even outdoors as well as offering a comfortable operational environment.

### 3.4 System Monitoring

With regard to the safe, secure operation of the energy storage system, this is monitored for faults and the battery data is recorded ( **Fig. 5** ).

**(1) Fault monitoring**

The energy system transmits the alarm information and measurement information via the FOMA cell phone network to the log server installed at NEC. Any critical alarm of the class causing system shutdown is transmitted by an e-mail to the cell phone of the registered maintenance personnel to ensure early fault detection.

The alarm functions of the energy storage system cover the following types of alarms.

- Voltage/current threshold monitoring for protection of the batteries.
- Company power grid abnormality monitoring (power failure, etc.)
- Power conditioner failure monitoring.
- System controller failure monitoring.
- Battery failure monitoring.

As the development of the present energy storage system is a new challenge for us, it is essential to check the behavior of equipment in detail regarding the safety of the lithium-ion batteries. Therefore, since the summer of 2011, specialized engineers have been appointed to monitor the above data.

**(2) Battery data measurement**

The battery data measured includes the voltage, current and wattage.

For enterprises introducing energy storage systems, the measured battery data serves to predict the electricity usage of customer households. On the other hand, the data serves to protect and monitor the condition of the batteries and, when this data is stored as the history of equipment evaluation results, it serves also to support the design of future energy storage systems.

With the present system, the energy storage system transmits battery data once a day for storage in a log server.

The data collected at fixed intervals is batch transmitted at every midnight.

**Table** shows the representative information sent as battery data.

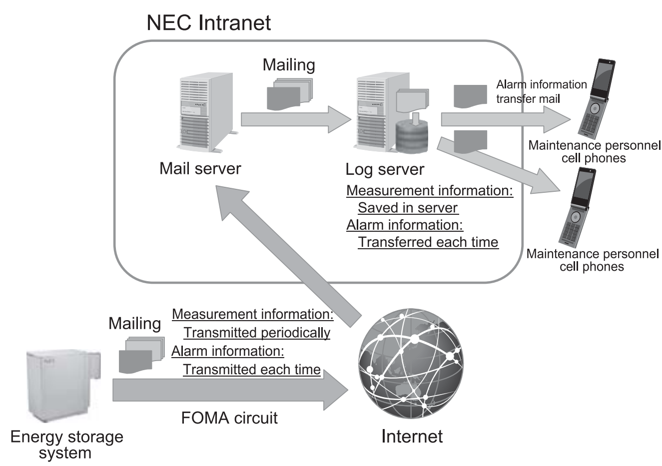


Fig. 5 Image of energy storage system surveillance.

Table Battery data.

| Battery data | Details |
|---|---|
| Output power | Wattage consumed by the load (W) |
| Key load power | Wattage discharged by the energy storage system (W) |
| Grid power | Wattage consumed by the load (W) |
| BATT voltage data | Battery voltage data (V)<br>(For use in overdischarge monitoring, etc.) |
| Current data | Battery current data (A)<br>(For use in overdischarge monitoring, etc.) |
| Remain data | Remaining battery amount data (%) |
| Module temperature | Battery temperature data (°C) (For use in battery protection) |

## 4. Conclusion

Since the summer of 2011 and in order to perform joint demonstration trials, we have been delivering a 6 kWh energy storage system based on the technologies described above to major housing manufacturers and energy-related enterprises. We are currently collating details of issues extracted from these trials so that we may incorporate improvement measures in the new product. This is being developed in collaboration with NEC Energy Devices and NEC Engineering, aiming at launch in the spring of 2012.

With regard to price reduction, which is the most important issue that affects the massive dissemination of household energy storage systems, we intend to stress the importance of cost reduction measures by utilizing the battery technology of the EVs, optimizing the costs of component parts and utilizing an SCM.

*FOMA is a registered trademark of NTT DoCoMo, Inc.

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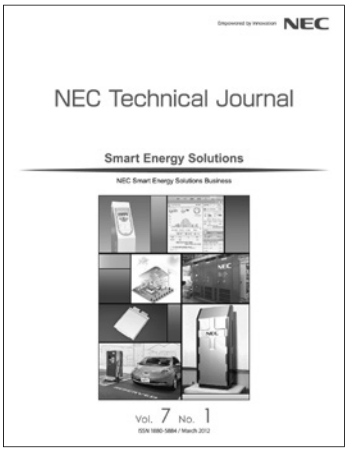



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