Featured Articles

Development of Appliances for All-electric Home and Residential Photovoltaic Power Generation Systems

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OVERVIEW: In addition to creating appliances for all-electric home use such as IH cooking heaters and the natural refrigerant heat pump water heater, Hitachi Appliances, Inc. is involved in the residential photovoltaic power system business. Hitachi's IH cooking heaters increase the maximum IH heating power to 3.2 kW (input value) while offering automatic double-sided cooking in the oven compartment, which has a grime-resistant internal structure, thereby reducing the time and effort needed for cooking and cleaning. The urethane foam-filled heat insulation structure utilized by the hot water storage unit in the natural refrigerant heat pump water heater for home use greatly improves energy-saving performance. Residential photovoltaic power generation systems contribute to energy generation by monitoring changes in sunlight and reliably generating power with a high-efficiency power conditioner.

INTRODUCTION

AWARENESS of the needs for saving energy and reducing energy consumption has been growing since the Great East Japan Earthquake of 2011. At the same time, as the population ages, expectations for a safe and secure lifestyle are also on the rise. It is against this background that appliances for all-electric homes such as induction heating (IH) cooking heaters and natural refrigerant heat pump water heater are expected to continue growing in popularity, thanks to their high energy consumption efficiency and the safety provided by avoiding the use of open flames. Not only do these products offer a high level of performance, they also enable the creation of new value from the perspectives of taste, amenity, and ease of use.

"Zero-energy houses" and other new types of homes are currently attracting a great deal of attention. The use of renewable energy as represented by photovoltaic power is a necessary part of achieving such homes, and Hitachi launched its own residential photovoltaic power system business in August 2012. This article discusses Hitachi's efforts surrounding three such products.

IH COOKING HEATERS

As products for FY2014, Hitachi developed the IH cooking heater HT-J300T (double all metal supporting three-burner IH) with a dedicated grill pan and high-power 3.2 kW (input value) IH heating, as well as the HT-J200T (all metal supporting three-burner IH) and HT-J100T (three-burner IH) series (see Fig. 1).

Featuring the Grill Pan

These products further advance oven cooking functionality while satisfying the need to be easy to clean, as emphasized by consumers when purchasing, by not only adopting a new oven structure that makes grime easy to remove, but by also combining delicious cooking results with reduced time and effort when cooking and cleaning.

This product uses a dedicated grill pan inside the oven to automatically cook both sides of the food, and this makes it possible to cook even hamburgers, grilled fish, and other dishes for which it is difficult to control the heat level appropriately, without needing to flip the food. In addition, 220 different oven recipes[*1] have been achieved, including 153 automatic menu types such as non-fried cooking, smothered cooking, bread, and others using the grill.

Temperature sensing was an important part of achieving an automatic menu using the grill pan. The temperature sensor mounted on the inside front of the oven is used to measure the amount of time required for the temperature to rise inside the oven,

*1 Number of recipes included in the "Oven Cooking Guide."

Fig. 1—Top Model in the HT-J300T Series (HT-J300XTWF [W]) (Top) and Grill Pan with Special Lid (Bottom).
Automatically cooks both sides of dishes such as hamburgers and grilled fish without requiring the time and effort for flipping the food. Automatic cooking also supports shrimp tempura without oil (non-fried cooking) and acqua pazza using the special lid (smothered cooking).

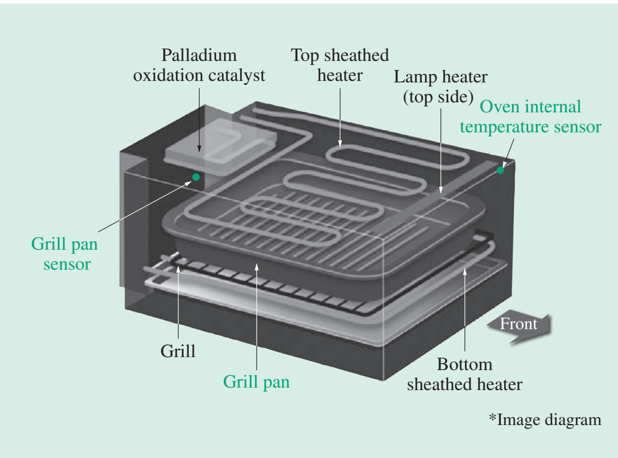

Fig. 2—Oven Unit Configuration Diagram.
An internal oven temperature sensor determines the amount of food being cooked, and the grill pan sensor determines how well the food is cooked.

which is used to compute the cooking time based on a determination of the amount of food being cooked. Furthermore, the grill pan's sensor is used to detect increases in temperature and determine how well the food is cooked to provide fine-tuned temperature control (see Fig. 2).

The grill pan uses a sheathed heater to cook food with a far-infrared and near-infrared radiation ratio

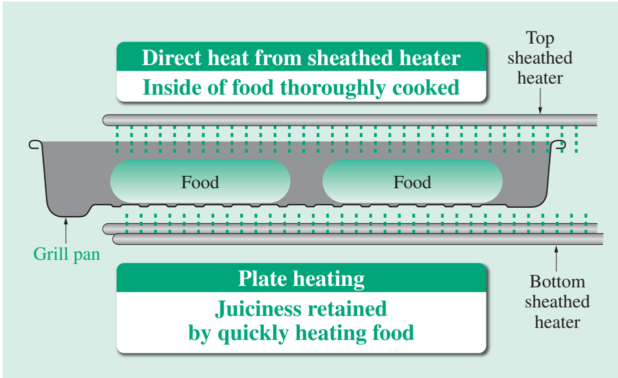

Fig. 3—Heater Image Diagram Using Grill Pan.
Heat is carefully applied from the top and bottom for delicious results.

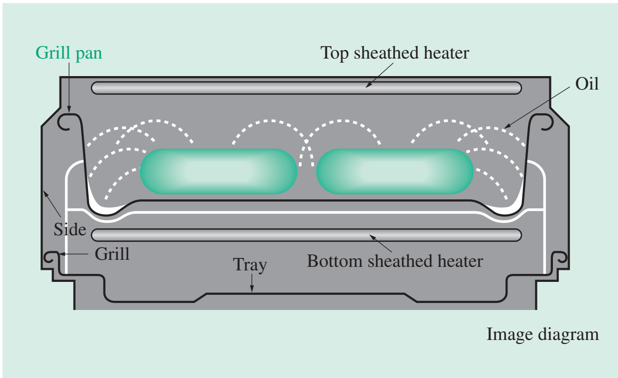

Fig. 4—Image Diagram of Reduced Grime in Oven.
The grill pan prevents oil from spattering and reduces grime on sides of oven.

of 8:2 (close to the ratio used during charbroiling), by grilling the top of food with direct heat while thoroughly cooking the inside. Next, a plate with good thermal responsiveness is used to heat up the grill pan to quickly transfer heat to the bottom of the food, thereby preserving juiciness. Top and bottom heaters are alternately powered in this way to meticulously control heating and provide delicious results (see Fig. 3).

When cooking with the grill pan at its depth of approximately 5 cm, this guards against the spattering of oil from the food, reducing the amount of grime that sticks to the inside of the oven after cooking. In addition, the grill pan is lightweight at approximately 500 g, and has a smooth fluorine coating that enables easy cleaning (see Fig. 4).

IH Heater with Powerful 3.2 kW-Input Heating

The biggest attraction of IH cooking heaters is the way they combine high efficiency with powerful heating capabilities, and the maximum heating power

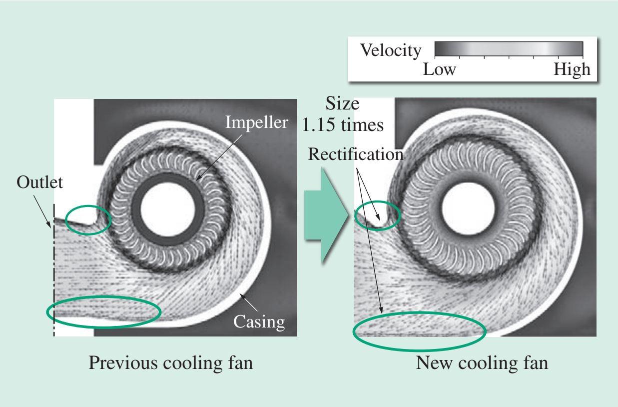

Fig. 5—Comparison of Computational Results of Previous and New Cooling Fans.
The new cooling fan has uniform velocity distribution at the outlet by rectifying along the casing.

of the left and right IH heaters in these products was increased from the previous 3.0 kW to a powerful 3.2 kW (when heating iron and stainless steel pots).

When it comes to providing strong heating power, the challenge lies in increasing the generation of heat in the inverters and coils. Inverter loss was reduced by lowering the capacity of the left and right IH inverters' resonance capacitors by 5% and bringing the circuit's resonance frequency closer to the inverter frequency. The cooling configuration features a new larger fan with an impeller diameter of approximately 1.15 times greater than before. The large-diameter impeller and large number of blades not only reduces noise, but it also provides 1.1 times as much cooling air. It also rectifies flow along the casing and homogenizes velocity distribution at the outlet, thereby improving the cooling effect on the electronic parts located downstream (see Fig. 5).

This stronger heating power satisfies the need for a shorter cooking time while speeding up the process of boiling large amounts of water for pasta and other such dishes.

NATURAL REFRIGERANT HEAT PUMP WATER HEATER FOR HOME USE

Approximately 30% of the energy consumed in the home goes toward the supply of hot water(1), so the promotion of energy conservation occupies an important position in the field of hot water supply. Natural refrigerant heat pump water heater for home use was newly added to the list of products covered by Top Runner standards in March 2013, as stipulated by the Energy Saving Act (Act on Temporary Measures for Promotion of Rational Uses of Energy and Recycled Resources in Business Activities) with a target year of FY2017, and so even greater efficiency is expected in the future.

It is against this background that Hitachi is focusing ongoing efforts on the development of improved energy-saving performance in natural refrigerant heat pump water heater for home use. The technology of products released in FY2013 garnered praise, earning Hitachi the Grand Prize for Excellence in Energy Efficiency and Conservation (Product Category & Business Model Category) in FY2013 as well as the Director-General's Prize, the Agency for Natural Resources and Energy*2.

Innovations in products for FY2014 resulted in the development of an industry-first*3 urethane foam-filled heat insulation structure in a hot water storage unit that provides up to approximately double the heat insulation performance*4. The high flow rate hot water supply series of high-efficiency models (see Fig. 6) combines a hot water storage unit with a urethane foam-filled heat insulation structure, vacuum heat insulating panels, and a high-efficiency heat pump

*2 Award-winning models: natural refrigerant heat pump water heater BHP-FV46ND for home use and others, for a total of 55 models.
*3 As of the release date of October 20th, 2014. Based on Hitachi research into natural refrigerant heat pump water heater hot water storage units for home use.
*4 Comparison of thermal resistance with previous Hitachi BHP-FV37ND product (2013 model, based on Hitachi research).

Fig. 6—Natural Refrigerant Heat Pump Water Heater BHP-FV37PD (Hot Water Storage Capacity: 370 L).
From the upper left: kitchen remote control, bathroom remote control, heat pump unit, and hot water storage unit exteriors.

unit to achieve the best energy-saving performance*5 in terms of annual water heating and heat-retention efficiency (JIS) two years in a row, at 3.9.

High-efficiency Hot Water Storage Unit Technology

Reducing heat loss in the hot water storage unit, or in other words, improving heat insulation performance, was indispensable when it came to improving the efficiency of the natural refrigerant heat pump water heater.

Previous hot water storage units (see the left side of Fig. 7) implemented heat insulation by combining segments of expanded bead polystyrene foam*6 (referred to as "expanded polystyrene (EPS)" hereinafter) around the body of the can used to store water (referred to as the "tank" hereinafter). To further improve the heat insulation performance of this product, Hitachi focused on developing and applying the "urethane foam-filled heat insulation structure" technology it has cultivated over many years in refrigerator manufacturing.

In the new heat insulation structure at the hot water storage unit (see the right side of Fig. 7), the tank is enclosed by a box-shaped outer panel, and liquid urethane is injected as a foam between the outer panel and the tank. In this way, the industry-first urethane foam-filled heat insulation structure with integrated enclosure was achieved. Heat insulation performance is greatly improved over EPS, not only by using urethane foam with its excellent heat insulation performance, but also by completely filling the enclosure to cover the entire tank (see Fig. 8).

Fig. 9 shows a comparison of the heat retention performance of the previous hot water storage unit and

*5 Current as of October 31st, 2014. For general-region home-use heat pump water heaters (1) annual water heating and heat-retention efficiency (JIS) 3.9 (three models including BHP-FV37PD, with hot water storage capacity equal to or greater than 320 L and less than 460 L), (2) annual water heating and heat-retention efficiency (JIS) 3.8 (three models including BHP-FV46PD, with hot water storage capacity equal to or greater than 460 L and less than 550 L).

*6 Foamed plastic formed by foam molding using polystyrene resin and a hydrocarbon-blowing agent (generally referred to as "expanded polystyrene").

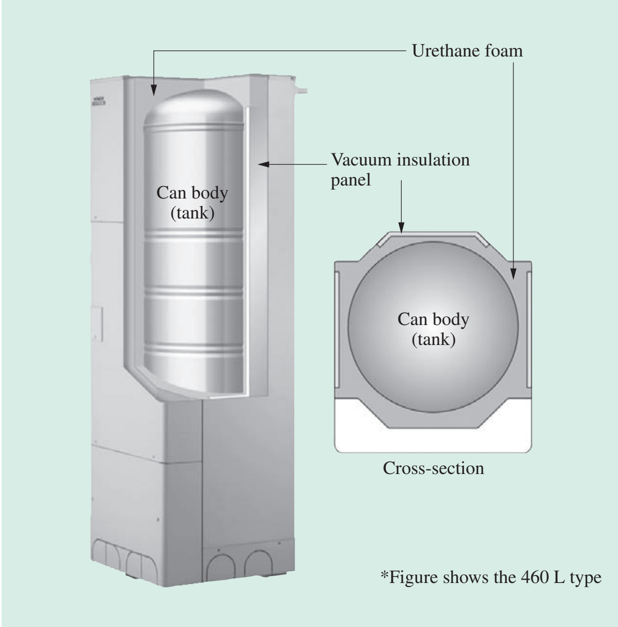

Fig. 8—Image of Urethane-insulated Storage Unit Structure (High-efficiency Model).
The entire tank is covered with urethane, without gaps. The high-efficiency model utilizes a structure that combines the urethane with vacuum insulation material.

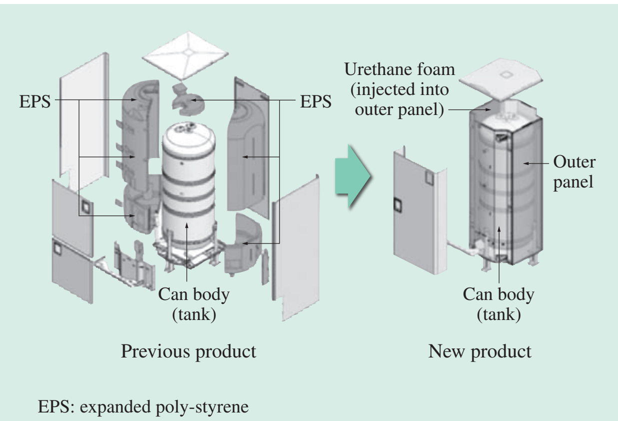

Fig. 7—Comparison of Hot Water Storage Unit Heat Insulation Structures.
The new heat insulation structure involves injecting liquid urethane between the outer panel and the tank, and then causing it to foam.

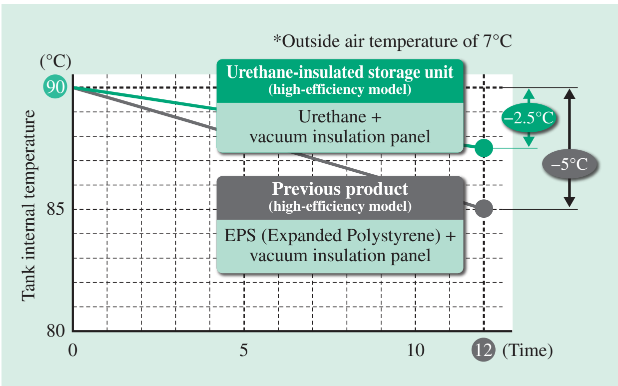

Fig. 9—Comparison between Heat Retention Performance of Urethane-insulated Storage Unit and Previous Product (High-efficiency Model).
In the case of the urethane-insulated storage unit the hot water only lost approximately 2.5°C when left for 12 hours at an external temperature of 7°C.

the urethane-insulated storage unit in high-efficiency models that improve heat insulation performance by combining vacuum heat insulating panels. Water is stored inside the tank at 90°C, and the figure shows how the water temperature decreases when the external temperature is kept at 7°C. Although the previous EPS heat insulation already offered good heat retention performance with a loss of approximately 5°C after 12 hours, the temperature inside the urethane-insulated storage unit only decreased by approximately 2.5°C, showing greatly improved heat retention performance.

Urethane foam filling and other improvements were used to strengthen the legs as well, and although a three-legged structure was retained for easy installation, it still achieved class S earthquake resistance[*7].

High-efficiency Heat Pump Unit Technology

Performance was improved in the elemental technologies (compressor, evaporator, etc) of the refrigeration cycle to increase efficiency in the heat pump unit (see Fig. 10).

A scroll compressor for carbon dioxide refrigerant with a unique oil supply structure that offers improved efficiency was adopted. Because oil is efficiently supplied in the compression chamber and other parts, sliding loss and heating re-expansion loss were reduced. Furthermore, the gap between fixed scroll and orbiting scroll was optimized to lower leakage loss, and overall efficiency is increased as a result.

Air-side heat transfer and the pressure loss characteristics of the evaporator were improved by optimizing the number of refrigerant pipe branches, the diameter of the refrigerant piping, and the shape of the aluminum fins. Generally refrigerant piping causes the increase of refrigerant pressure loss, and in order to solve this problem, equal refrigerant distribution was achieved with multiple branches by developing mist flow distribution technology whereby the refrigerant in the mist flow state is branched immediately after the expansion valve. Heat transfer performance was also improved by optimizing the refrigerant flow path and arranging the paths at a high density while keeping the wetted and superheated flow paths apart from each other.

*7 Class S earthquake resistance means that the design standard for an earthquake intensity of 2.0 is met from the "Building Equipment and Device Design Standard Earthquake Intensity Based on the Local Earthquake Intensity Method" of the "Seismic Design and Construction Guide for Building Equipment" (Building Center of Japan). Test condition: Confirmation that the device can withstand having a continuous load of twice the mass of a full tank of water in the direction of the weak axis on the center of gravity, while fixed using the method described in the installation manual with a full tank of water in the device. (Models with class S earthquake resistance: P series 460 L released in October 2014, in 370 L hot water storage unit [N series 460 L and 370 L models have class A earthquake resistance, and other models have class B earthquake resistance].)

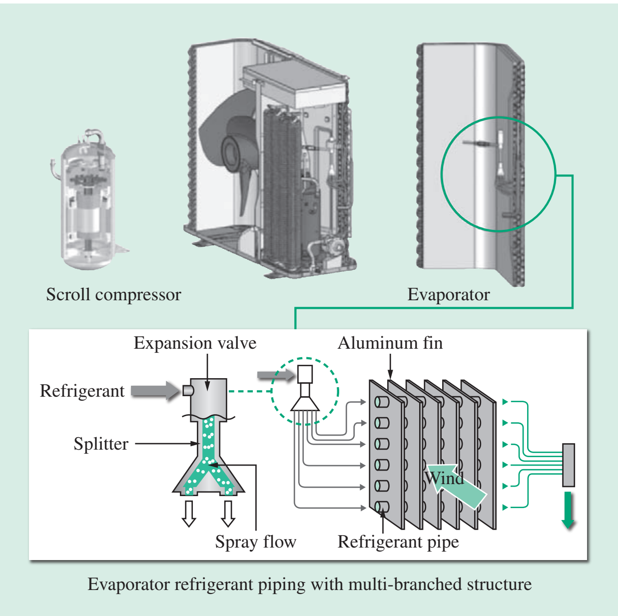

Fig. 10—High-efficiency Heat Pump Unit Technology.
High efficiency is achieved by applying ingenious techniques to various parts inside the unit.

Tap Water Direct Pressure Hot Water Supply Method and Amenity Functions

Products in the high flow rate hot water supply series use tap water pressure without decompression to instantly supply water by using a tap water direct pressure method exclusive to Hitachi (see Fig. 11). This system enables, for instance, the simultaneous use of hot water in two locations such as the shower in the bathroom and the kitchen, while still providing hot water at high pressure in the shower. Application of this tap water direct pressure technology has enabled Hitachi to provide a lineup of products that also support both well water and hard tap water.

The high-efficiency model released in FY2014 not only ranks first in energy conservation, it also provides a rapid hot water filling function that can fill a bath with hot water within about five minutes (approximately 50% faster than standard bath-filling time[*8]), as well as a "comfortable bubble bath" function that combines a water jet with bubbles for a pleasing effect (see Fig. 12). This product provides both ease of use and a high level of amenity.

*8 Pipe diameter 15 A, 5 m straight pipe, water supply pressure 300 kPa. Tank hot water temperature 80°C, cold water temperature 17°C, bath filled to 180 L at a temperature of 40°C, requiring approximately 5 minutes 45 seconds.

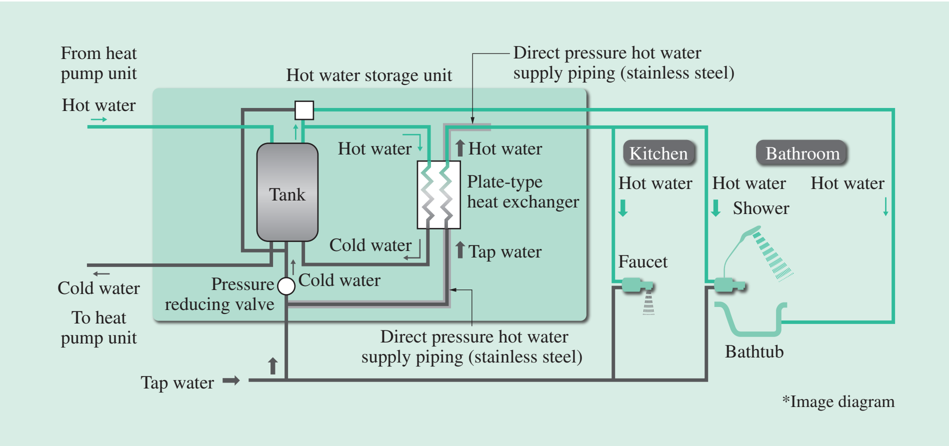

Fig. 11—Tap Water Direct Pressure Hot Water Supply Mechanism.
A plate-type heat exchanger is used to instantly heat water and supply hot water while essentially leaving the tap water's pressure and water quality as is.

Fig. 12—"Comfortable Bubble Bath" Jet and Bubble Image.
Jet and bubbles provide a soothing bath.

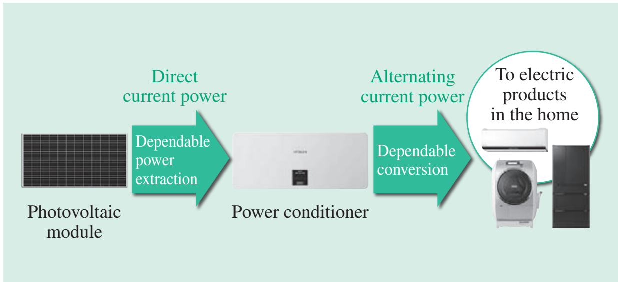

Fig. 13—Power Conditioner Roles.
A power conditioner converts direct current power generated by the photovoltaic module into alternating current power.

All models support connection to a Home Energy Management System (HEMS)*9 (a HEMS adapter for connecting to a water heater is required and sold separately).

HIGH-EFFICIENCY POWER CONDITIONER FOR USE IN RESIDENTIAL PHOTOVOLTAIC POWER GENERATION SYSTEMS

Power conditioners provide two functions by drawing direct current power from photovoltaic modules and converting that direct current power into alternating current power. Hitachi sought to develop a product that could maximize power generation in both functions (see Fig. 13).

Function for Producing Direct Current Power

The amount of photovoltaic power that is generated will depend on factors such as the weather, with different amounts generated on sunny and cloudy days. Partial shadows of trees, utility poles, buildings, and other objects falling on photovoltaic modules can also have an effect.

Using general maximum power point tracking (MPPT) control(2), which produces power from photovoltaic modules, the voltage is changed in order to search for the photovoltaic module's power generation peak point. When partial shadows occur at this time, multiple peak points exist in the power-voltage (P-V) characteristic curve of the photovoltaic module, and this may make it impossible to find the peak point for maximum power, with the result that the generated power is less than the actual power generation capacity.

This is why Hitachi has developed a unique "HI-MPPT (Hitachi's unique MPPT)" control system that enables the generation of more power, even when partial shadows occur.

With HI-MPPT control, the fluctuation of power generation peak points is monitored during MPPT control, and when a fluctuation due to partial shadowing is detected, the overall P-V characteristic curve is evaluated to determine multiple peak points and resume MPPT control at the peak point, with the highest level of power generation (see Fig. 14).

By monitoring fluctuations in power peak points due to changes in sunlight, this function reduces loss in power generation and provides reliable electric power.

*9 A system designed to enable the efficient use of energy by connecting devices in the home via a network.

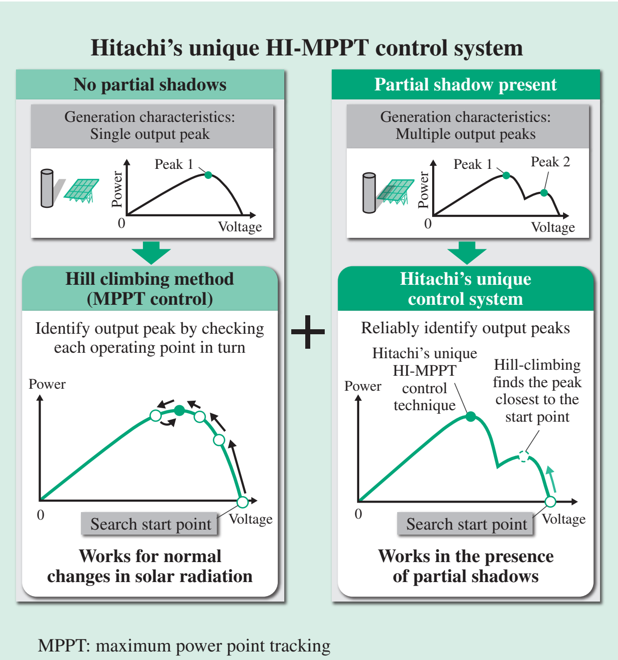

Fig. 14—HI-MPPT Control Characteristics Due to Power Generating Characteristics of Photovoltaic Modules.
HI-MPPT monitors fluctuations in electric power peak points due to changing sunlight in order to generate power.

Function for Converting Direct Current to Alternating Current Power

A silicon carbide–Schottky barrier diode (SiC-SBD) is used in the converter that performs step-up transformation on the direct current power generated by photovoltaic modules to greatly reduce recovery loss during switching. This makes it possible to increase the switching frequency to 40 kHz, and reduces loss through implementation of a compact direct current (DC) reactor.

Hitachi developed a new pulse width modulation (PWM) control method to inhibit waveform distortion in the output current of the inverter that converts direct to alternating current power, while lowering the number of switches down to one-quarter of that used previously. This enabled implementation of a power conditioner that achieves a rated conversion efficiency of 96%*10 (see Fig. 15).

CONCLUSIONS

The three products discussed in this article (appliances for all-electric homes and photovoltaic power generation systems) are still relatively new, but they are already contributing a great deal toward conservation of the global environment, and the societal responsibility involved is heavy. Even further improvements in performance will be required. Hitachi will continue developing products that satisfy the demands of society and consumers from a unique perspective.

*10 Rated load efficiency as stipulated by JIS C 8961.

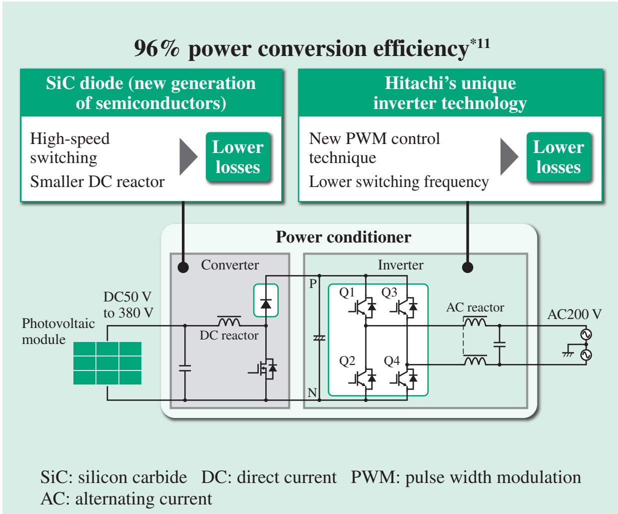

Fig. 15—Improvements to Power Conversion Efficiency of Power Conditioner.
Unique inverter technology is used to efficiently convert direct current power into alternating current power.

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