

Increasing Capacity and Efficiency of Energy Harvesting Power Supplies in Zero Energy IoT Series

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In recent years, the need for visualization and automation has increased in a wide range of fields, including countermeasures against aging social infrastructures / natural disasters, and monitoring agriculture / natural environment. This has led to the widespread use of outdoor IoT (Internet of Things) devices. However, securing power sources outdoors is a challenge as it often necessitates wiring work or periodic battery replacement. Energy harvesting technology, which converts minute amounts of energy from the environment into electricity, is effective in powering IoT devices. The application of energy harvesting technology eliminates the need for battery replacement, enabling a longer period of maintenance-free operation.

OKI currently offers the Zero-Energy IoT Series, including the Zero Energy Gateways, which is a series of solar powered devices that transmit data collected on-site to the cloud via LTE communications. **Figure 1** shows an overview of the Zero Energy Gateways' operation. In addition to the standalone gateway that relays data measured by sensors, such as an acceleration sensor, to the cloud via 920 MHz multi-hop wireless (SmartHop)¹⁾, the lineup also offers models equipped with a high-sensitivity camera and a water level gauge.



Figure 1. Zero Energy Gateways

The products have been used to remotely monitor the integrity of infrastructures, bridges and other structures in a variety of demonstration experiments, leading to the adoption by many clients^{2), 3)}.

In response to clients' requests and issues identified through these on-site operations, and an eye toward

further expanding the Zero-Energy IoT Series' fields of use, OKI is developing a next-generation energy harvesting power supply that will be "large capacity" to improve power generation and charging capabilities, and "multi-source" to support power sources other than solar energy. This article introduces OKI's efforts in developing a new energy harvesting power supply.

Overview of Energy Harvesting Power Supply

Figure 2 shows the configuration of the newly developed energy harvesting power supply (hereinafter referred to as the EH power supply). The following configuration and operation characteristics are the key points for the improved functionality and performance.

- (1) Increased power generation and storage capacity:
Increased power generation and storage capacity allows for more frequent data acquisition and more power-intensive operations.
- (2) Improved power generation efficiency:
Improved power generation efficiency allows operation in a wide range of lighting conditions, from low to high illumination.
- (3) Support for other power sources:
Support for power sources other than solar energy allows more flexibility in installation locations.

The background and overview of each feature are given below.

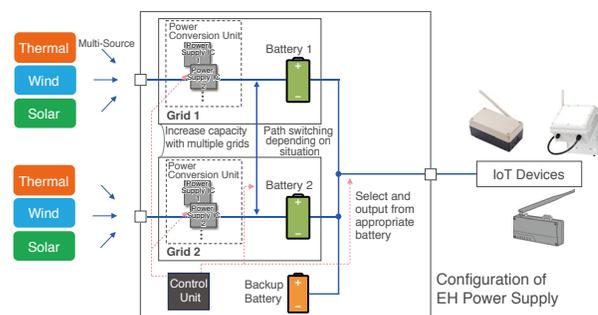


Figure2. Configuration of EH Power supply

1) Increased Power Generation and Storage Capacity

The current Zero Energy Gateways can be equipped with cameras and water level gauges that acquire and transmit data at set intervals, but there are situations where more frequent operation cycles are required. In particular, there is an increasing demand for cameras to capture images and transmit data more frequently, allowing a more detailed understanding of on-site conditions. In order to support such power-intensive applications, increased power generation and storage capacity are required.

The following two features were implemented in the EH power supply to increase power generation and storage capacity, thereby enabling the support of applications with higher power loads.

(1) Increased Capacity through Multiple Power Grids

The EH power supply has two power grids consisting of power converters and storage batteries. It can be connected with two power sources such as solar panels, two storage batteries, and one backup battery in case of a drop or interruption in power generation.

As shown in **Figure 3**, the EH power supply has a crossing charging path connecting the power grids. The charging path is switched depending on the charge status of the batteries. For example, as shown in **Figure 3** (IV), if the battery on grid 1 is fully charged and the battery on grid 2 has capacity available for charging, the path is switched allowing power generated on grid 1 to charge the battery on grid 2. This dynamic switching ensures the generated power is utilized efficiently for charging the batteries.

In addition, the output section of the EH power supply seamlessly switches between the two storage batteries and the one backup battery. The appropriate battery is selected automatically based on battery voltage, ensuring a stable supply of power from multiple batteries.

Dynamically switching the charging paths and the used battery allows multiple power sources and batteries to operate as a single power supply system, making it possible to increase power generation and storage capacity. As shown in **Figure 3**, there are four ways to use the multi-grid system depending on the number of power sources and storage batteries connected. They are expected to be used in the following situations.

(I) Single grid system (similar to current operation)

This is the standard configuration and used for applications that can operate with a single power source and single storage battery.

(II) Increased storage capacity

The system can be operated more reliably by storing more electricity when there is sufficient power generation and preparing for power generation shortages due to seasonal or environmental changes.

(III) Increased power generation

In environments with little sunlight, a more stable power generation can be achieved by combining and charging with two power sources, such as two solar panels or a combination of power sources with different generation methods.

(IV) Increased power generation and storage capacity

Through the increased power generation and storage capacity using two grids, the system can accommodate applications with higher power loads.

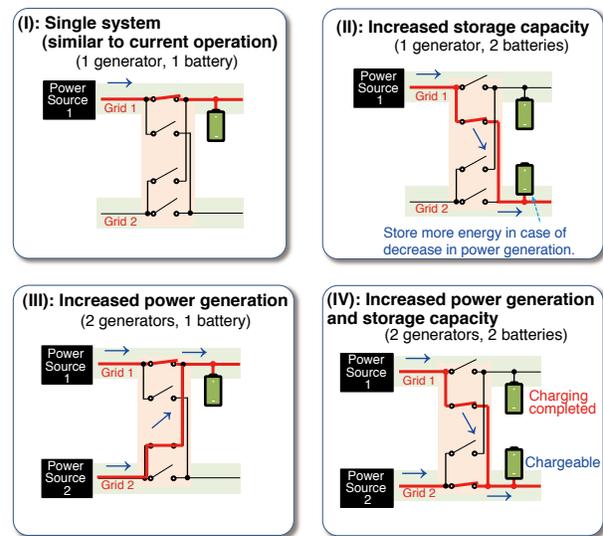


Figure 3. Multi-Grid Systems using Different Power Sources and Storage Connections

Additionally, the system has a backup battery in case the storage battery loses charge due to a drop or interruption in power generation. By switching to the backup battery, the system can continue to operate even in situations when power generation is difficult and the storage battery runs low. The backup battery uses a power unit designed for outdoor equipment and a primary battery with little self-discharge capable of storing power for a long period of time, and it can be expanded as necessary.

(2) Accommodation for High-Output Solar Panel

The EH power supply's power converter has an output capacity that is approximately three times more compared to the previous system, improving the power generation per grid. This allows the system to support higher output power sources than the previous system. **Figure 4** shows

a comparison of the power generation when the EH power supply is connected to a solar panel used in the current Zero-Energy Gateway and to a high-output solar panel. In the example shown in **Figure 4**, the power generation of the high-output solar panel is approximately three times greater than the current panel under the same power generation environment.

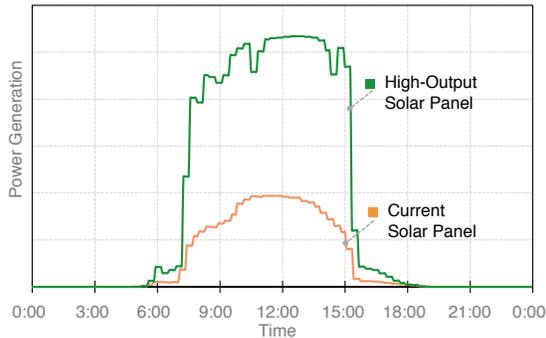


Figure 4. Comparison of Power Generation Between Current and High-Output Solar Panels

2) Improved Power Generation Efficiency

Solar panels are widely used for energy harvesting since they can generate power anywhere sunlight is available and can easily secure the level of power required for device operation. However, the locations where devices need to be installed do not always have sufficient sunlight. Therefore, improving power generation not only in environments with ample light but also in environments with low light will enable a more stable supply of power and expand the option of where devices can be installed.

To extract the maximum amount of generated power from a power source, it is necessary to consider the point at which the power is at a maximum. **Figure 5** shows an example of the changes in output voltage and power (output current x voltage) when the load (output current) is gradually changed for a certain power source. Since voltage varies with the magnitude of the current, there is a point at which power is maximized. By generating power at such a point, more power can be obtained even under the same environmental conditions. Furthermore, the point at which maximum power is obtained from solar panels changes depending on conditions such as the amount of sunlight and temperature. Therefore, power generation can be maximized by switching to an appropriate point according to environmental changes.

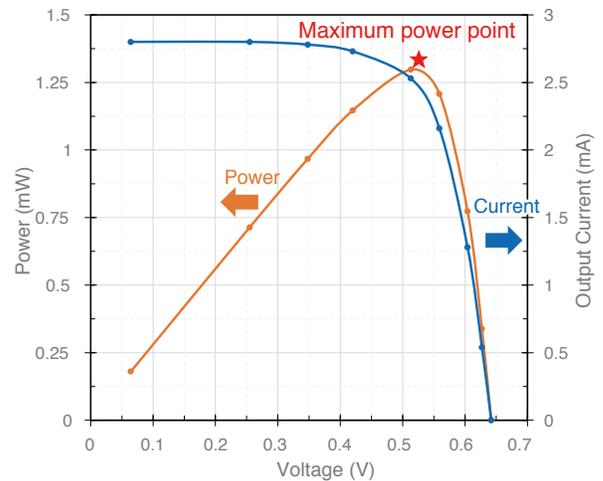


Figure 5. Changes in Power Source's Current-Voltage Characteristics and Power

The EH power supply has a unit that controls power generation and charging paths, and is characterized by maximizing power generation even when the environment changes by periodically updating the power point for maximum charging current. **Figure 6** shows the power generated by the EH power supply and the conventional generator unit of the Zero Energy Gateway for various illuminance levels. Although the same solar panel was used for comparison, it can be seen that the EH power supply generates more power at low illuminance levels of 20,000 lx or less and at high illuminance levels of approximately 40,000 lx or more. While the current Zero Energy Gateway has a fixed operating point, the EH power supply achieves high efficiency in both low and high illuminance levels by switching to an optimal operating point.

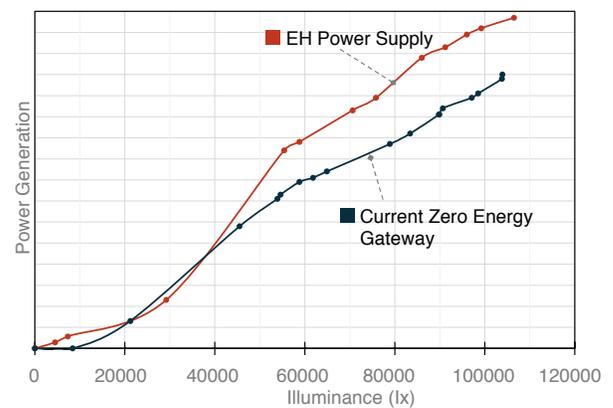


Figure 6. Comparison of Current and New Power Supplies

*1) Flexiina is a registered trademark of E-thermoGentek Co., Ltd.

3) Support for Other Power Sources

As mentioned previously, solar panels are used in many energy harvesting devices. However, it is difficult for the solar panels to generate sufficient power indoors or other places with limited sunlight. Therefore, if power can be harvested from other sources, such as vibration, wind, and heat, it would expand the application fields for IoT devices.

The EH power supply can be used with various sources of power generation by changing the power supply IC according to the voltage and power of the source. Although the maximum power point shown in Figure 5 will vary depending on the type of power source, the power point switching function described previously allows for highly efficient power generation even with sources other than solar panels. An alternative source of power generation that OKI considered was thermoelectric generation, which utilizes temperature differences. OKI is evaluating the combination of its EH power supply with E-thermoGentek Co., Ltd.'s Flexiina[®] 4). ¹⁾. An overview of thermoelectric generation and Flexiina are described below.

Thermoelectric generation utilizes the temperature difference created by keeping one end of a thermoelectric conversion element hot and the other end cold. Flexiina is a flexible, sheet-like thermoelectric conversion module that can be adhered and installed in curved pipes, achieving high heat recovery efficiency. While technologies for recycling high-temperature waste heat have been in practical use for some time, efficient energy recovery of low-temperature waste heat below 150°C has been difficult, resulting in much of the heat remaining unused. Flexiina is characterized by its ability to effectively generate power even from low-temperature waste heat below 150°C, and it is attracting attention as a new waste heat recovery technology. Due to this characteristic, there is expectation that the technology can be used to turn the piping inside factories and plants into a power generation source for powering indoor infrastructure monitors.

Figure 7 shows the relationship between the temperature difference and the amount of power generated when Flexiina was combined with the EH power supply. Using a Flexiina (S1-P1B) with integrated heat dissipation fins that is 60 mm wide and 30 mm high, it was found that the current Zero Energy Gateway can be operated if a temperature difference of approximately 50°C is achieved between room temperature and the heat source.

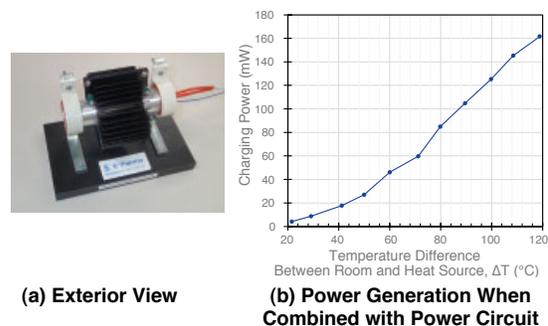


Figure 7. E-ThermoGentek Co., Ltd.'s Flexiina

Conclusion

This article introduced an energy harvesting power supply that achieves large-capacity power generation and storage, improved power generation efficiency, and compatibility with various power generation sources (multi-source). The technology expands the operating range of energy harvesting devices and enables the operation of applications that require more power. OKI will apply the technology to energy harvesting devices, including the Zero Energy Gateways, to provide IoT devices that achieve more frequent and stable operation ◆◆

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