Zero-Energy IoT Series -Realize Remote Monitoring of Infrastructure and Disaster Site with Easy Installation-

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Natural disasters have become more severe in recent years due to climate change, and the need to check site conditions in the event of a disaster, as well as to inspect and repair aging infrastructure is increasing. However, there are issues of cost and labor shortage associated with these tasks.

To address these issues, OKI has developed the “Zero-Energy IoT Series” infrastructure monitoring system that can remotely monitor the integrity of infrastructures such as bridges, slopes, and steel towers, and check the condition of sites when disaster strikes. Through the use of this system, OKI is working to realize disaster prevention DX that supports infrastructure administrators’ maintenance and disaster response operations.

This article introduces the features and usage examples of the “Zero-Energy IoT Series.”

Overview

The Zero-Energy IoT Series developed by OKI is an infrastructure monitoring system consisting of sensors and gateways. It requires no power supply or wiring, therefore it is easy to install. Using various sensors, it can measure the inclination and natural frequencies of infrastructures or water levels of rivers. It can also be equipped with a high-sensitivity camera to capture clear images of a site day or night. Infrastructure administrators can view sensed data and captured images via the cloud using a browser on a remote computer or smartphone. **Figure 1** shows the system configuration.

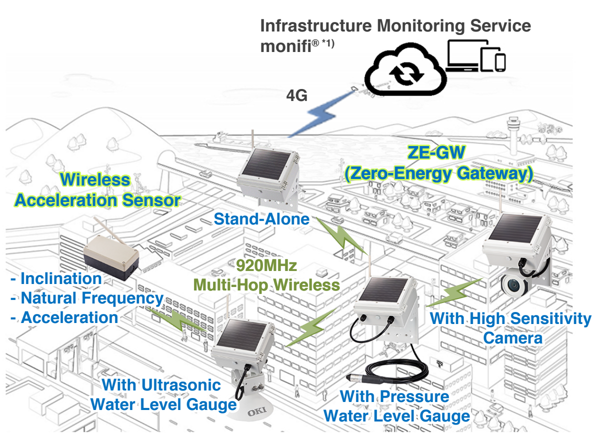

Figure 1. System Configuration

Usage Scenarios

Infrastructure administrators of bridges, slopes, steel towers, etc. often visit sites to conduct inspections in order to confirm the integrity of infrastructures or assess the site situation in the event of a disaster. In these cases, issues arise such as the time required to travel to a site, the cost of inspection work, and the safety of personnel heading to the disaster site. With the use of OKI’s system, the condition of infrastructures, river water levels, and on-site images can be monitored remotely. This will reduce the number of on-site inspections, thus improve efficiency of maintenance work and safety of personnel. **Figure 2** shows the usage scenarios of the system.

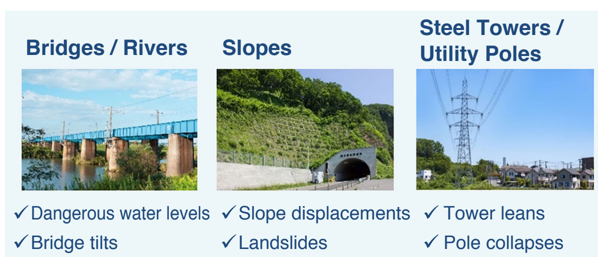

Figure 2 . Usage Scenarios

Features

The major feature of the Zero-Energy IoT Series is that it does not require any wiring work for power supply or communication, and together with its small size makes it easy install almost anywhere. Its high-precision measurements, high-sensitivity camera shots, environmental resistance for outdoor operation, and high reliability, which are all required for infrastructure maintenance work, are also big features.

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The wireless acceleration sensor uses advanced sleep control and power-saving 920MHz multi-hop wireless technology to enable long battery life. If inclination measurements are taken once every 10 minutes, the battery will last five years. The casing is both waterproof and dustproof, and its small size of approximately 140mm longitudinally makes it easy to install at outdoor sites. It is capable of measuring inclination angles in 0.01 degree increments in two directions simultaneously enabling it to monitor slight changes in the inclination of a structure. Additionally, edge processing within the device converts acceleration data into a frequency spectrum from which it automatically calculates the frequency at which the intensity peaks (natural frequency), and monitors its changes. A five-minute raw acceleration data used for calculating the natural frequency is approximately 590KB, while the natural frequency data calculated from the raw data is approximately 0.83KB, thus the amount of data to be sent can be reduced to about 1/700. This significantly reduces the amount of data to be sent to the server when compared with directly sending the raw acceleration data. This edge processing reduces the power consumption required for data transmission, and if natural frequency is measured four times a day, the battery life is five years. Moreover, since the load on the wireless network is reduced, a single gateway can accommodate 20 sensors, allowing for flexible network construction. **Photo 1** shows the exterior view of the wireless acceleration sensor, and **Table 1** shows its specifications.

The main unit aggregates data measured by each sensor, such as the wireless acceleration sensor, and sends it to the cloud using the Zero-Energy Gateway (ZE-GW).

Conventional base units run on external power source that require troublesome and costly wiring work during installation. On the other hand, ZE-GW is solar powered, and it has wireless communication functions using 4G and 920MHz multi-hop wireless. This allows easy installation since the need for power and communication wirings is eliminated. Power savings from its advanced sleep control enables the unit to operate up to nine consecutive days without sunlight making it suitable for long-term stable operation. **Photo 2** shows the exterior view of the ZE-GW, and **Table 2** shows its specifications.

Photo 1. Wireless Acceleration Sensor

Photo 2. ZE-GW

Table 1. Wireless Acceleration Sensor Specifications

Communication Function		920MHz multi-hop wireless
Sensing Functions	Acceleration	Measurement axes: 3, Sampling: 125Hz, Range: ±2G
	Inclination	Measurement directions: 2 Resolution: 0.01°, Accuracy: ±0.1°
	Frequency Analysis	Frequency spectrum, natural frequency distribution
	Device Monitoring	Internal temperature and humidity Battery voltage
Power		Cylindrical lithium battery CR17450
Battery Life		5 years (when inclination measured every 10 minutes and natural frequency distribution measured 4 times/day)
Operating Condition		-20 to 60°C, 10 to 95% RH with no condensation
Water/Dust Resistance		IP65 compliant
Dimensions		(W)76 × (D)140 × (H)60mm (excludes antenna and protrusions)
Weight		Approximately 530g (includes battery and antenna)

Table 2. ZE-GW Specifications

Communication Function	920MHz multi-hop wireless LTE-Cat. M1
Power	Solar powered
Battery Capacity	9 consecutive days without sunlight
Operating Condition	-20 to 60°C, 10 to 95% RH with no condensation
Water/Dust Resistance	IP65 compliant
Device Monitoring	Internal temperature and humidity Battery voltage
Dimensions	(W)230 x (D)284 x (H)378mm (excluding antenna and protrusions)
Weight	Approximately 4kg

In addition to the stand-alone unit, ZE-GW has a lineup that includes units integrated with ultrasonic water level gauge, pressure water level gauge, and high-sensitivity camera. **Photo 3** shows the views of these units.

(Left) With Ultrasonic Water Level Gauge
(Center) With Pressure Water Level Gauge
(Right) With High-Sensitivity Camera

Photo 3. Zero-Energy Gateways (ZE-GW)

The ultrasonic water level gauge emits ultrasonic waves from directly above the river's water surface and measures the water level based on the time it takes to receive the reflected waves. Similar to the main ZE-GW unit, the measurement unit also does not require wiring, and the installation remains easy. The measurement accuracy is high at ±10mm. With the pressure water level gauge, the measurement unit is installed in the river water to directly measure the water pressure. Therefore, there is no need to install the unit above the water surface, and this unit type can be selected depending on the installation environment. In both types, the measurement unit is integrated with the main ZE-GW unit, and they are capable of operating for nine days without sunlight making them suitable for long-term stable operation.

The high-sensitivity camera unit is equipped with a camera module developed by OKI that consumes little power, but enables clear images to be shot and viewed remotely even in low-light environments such as at night. The camera unit is able to operate in conjunction with each of the sensor units, and when a measured inclination, acceleration, or water level exceeds the threshold, an alarm sent wirelessly from a sensor can trigger the camera to immediately start shooting and automatically change the shooting interval. The high-sensitivity camera integrated with the main ZE-GW unit is also capable of operating nine days under non-sunlight condition.

As was described, the Zero-Energy IoT Series has a lineup of various highly accurate sensors and camera that is easy to install, and the system is already being used at infrastructure maintenance and management sites. The next section will introduce some examples of its implementation.

Implementation Examples

(1) Bridge Monitoring

With the aging of bridges and the increasing number of torrential rains, there have been incidents where rise in the water level due to heavy rain scours away the riverbed causing aging bridge piers to tilt. For this reason, it is important to assess the on-site situation when heavy rains occur and to inspect bridges at risk from scouring after the rain passes. However, to physically send personnel to sites and perform tasks, securing manpower and ensuring the personnel's safety become issues.

These issues can be solved with implementation of the Zero-Energy IoT Series. It will allow the infrastructure administrator to remotely assess the on-site situation, thereby improving work efficiency and ensuring safety.

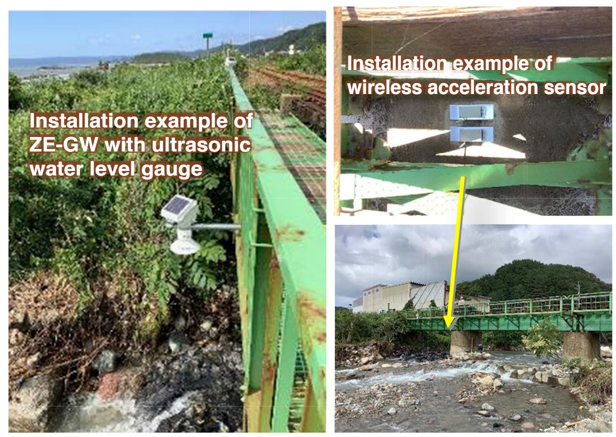

Figure 3. Installation on Railway Bridge

Figure 3 shows an example of a wireless acceleration sensor and ZE-GW with ultrasonic water level gauge installed on a railway bridge. The wireless acceleration sensor installed at the top of the bridge pier measures inclination and natural frequency to monitor changes. As scouring progresses, the natural frequency decreases and the risk of tilting increases. Conventionally, for bridges where scouring is a concern, an impact vibration test is conducted. The test involves pounding a heavy weight against the pier and measuring the natural frequency from the forced vibration. This test is conducted periodically or when heavy rain occurs. However, it takes time and labor to transport the weight to the site and perform the pounding. In contrast, when a wireless acceleration sensor is implemented, changes in the natural frequency can be automatically monitored remotely reducing the number of on-site measurements.

Additionally, by installing a ZE-GW with ultrasonic water level gauge on a fixed pipe extending from the girder, the river water level can be monitored remotely. This is useful for checking the water level during and after a heavy rainfall to confirm safe operation of the trains.

There are also examples of ZE-GW with high-sensitivity cameras being installed on bridges. The status and water level at bridges can be checked remotely with clear images day or night, thus reducing the number of on-site inspections that a personnel must make and streamlining operations.

(2) Slope Monitoring

Due to the effects of heavy rain, landslides occurring on slopes are increasing and confirming the safety around slopes is becoming important. If there is a concern that landslides may occur near railways, roads, or steel towers, infrastructure administrator may visit the site periodically or when heavy rain occurs to visually check the condition.

In such a situation, the implementation of a Zero-Energy Gateway equipped with a high-sensitivity camera will enable remote monitoring of the slope condition when heavy rain occurs. **Figure 4** shows an example of images shot during slope monitoring. High-sensitivity photography takes clear photos even at midnight when there is no lighting and allows the slope condition to be remotely monitored regardless of the time of day.

Figure 4. Example Images from Slope Monitoring

There are also examples of slope monitoring that combines a wireless acceleration sensor with the high-sensitivity camera. **Figure 5** shows an example of a system using such a configuration. The wireless acceleration sensor is installed on a pole set on a slope. During heavy rain, earth and sand movements on the slope are detected by monitoring the changes in the pole's tilt. If the wireless acceleration sensor detects a change in the tilt, it will send out an alarm notification. When the high-sensitivity camera receives this notification, it will immediately begin taking photos and also shorten the interval between shots. In addition to landslides, it is also possible to perform similar monitoring in areas where rockfall is a concern by installing wireless acceleration sensors on fences that protect against rockfall.

Figure 5. Configuration Example of Slope Monitoring System

Conclusion

OKI's Zero-Energy IoT Series features easy installation and high reliability with power-saving, sensing, wireless network, and data analysis technologies. Monitoring of bridges and slopes were presented as examples of how these features are utilized to support infrastructure administration and disaster response operations. OKI will work to expand its product lineup with the addition of other sensors such as strain and displacement sensors to further contribute to the efficiency improvement of infrastructure administration, ensure safety, and open opportunities for more use cases.

The intensification of natural disasters due to climate change and aging of infrastructures are not limited to Japan, but common problems throughout the world. OKI aims to expand disaster prevention DX using the Zero-Energy IoT Series to the global market, and work to develop technologies and products for this purpose. ◆◆

Authors

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TIPS 【Glossary】

Scouring
A phenomenon in which earth and sand on riverbanks, riverbeds, coasts, and the ocean floor are washed away by running water and waves. Scouring can cause bridges to collapse or wash away.