Development of Sensing Systems for Status Monitoring of Rotary Machines

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Abstract

For infrastructure facilities like rotary machines, it is important to grasp early warning signs of failure in order to reduce downtime due to failure-induced shutdown.

We have developed a sensing system that can continuously grasp the conditions of facility equipment by mounting surface-attached sensors on existing equipment to be monitored. This sensing system has features that (1) makes remote operation possible, (2) does not need any modification on infrastructure equipment and (3) is easy to install.

In addition, if this sensing system is used with a system of Internet of Things (IoT), we can utilize large data for our customer's facility renovation project proposals. This includes a prediction of remaining infrastructure facility's operation life and drafting facility renovation plans.

Currently, we are conducting various on-site verification tests at either our factory facilities, or the customer's facilities.

1 Preface

Rotary machines are used as power sources or generators to support infrastructure facilities. They are generally used for a long duration of time of more than 20 years. If these facilities unexpectedly fail, it has a detrimental impact on social infrastructure. It is, therefore, important to grasp early warning signs of failure before the occurrence of failure of rotary machines. In the conventional method, we conduct periodic inspection to check the fitness of equipment. Recently, there has been a growing interest on Condition Based Maintenance (CBM) to actively manage the conditions of equipment in order to immediately perform maintenance when it is needed.

We have developed a sensing system for the purpose of preventive maintenance for existing rotating machines. A sensing system is a system in which sensors are installed on a rotating machine and the sensor data is continuously collected. This article introduces this sensing system.

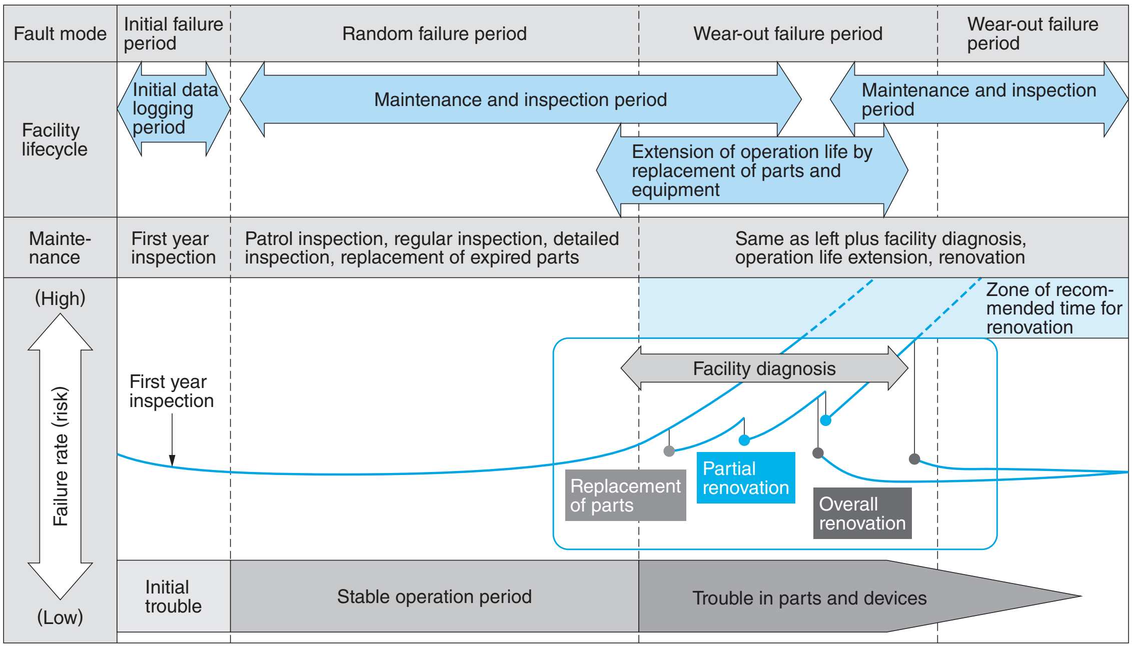
2 Issues in the Maintenance of Infrastructure Equipment

Infrastructure facilities are used for a long duration of time and there is a negative impact when there is a shutdown due to failure. For this reason, it is important to properly maintain and inspect infrastructure facilities. Fig. 1 shows the model of a electrical equipment failure rate. Equipment that has passed the stable performance period tends to face equipment challenges due to the wear of materials and failure of its parts. By performing equipment diagnosis during such stages of equipment and conducting proper repairs and parts replacement, the equipment can be used stably for a longer periods of time. Facility maintenance, however, has the following three issues.

(1) It is difficult to continuously monitor operating status.

Regular periodic inspections are performed once every month, and up to once a year. For this reason, if an anomaly occurs in the equipment between inspections, the equipment anomaly may have worsen leading up to the next inspection.

(2) It is difficult to secure trouble-shooting personnel in the event of a sudden failure.



Source: Edited in accordance with The Japan Electrical Manufacturers' Association: "Are your substation facilities already diagnosed? Recommendation of diagnosis, maintenance, and inspection for your facilities"

Fig. 1 **Model of Electrical Equipment Failure Rate**

Time-serial changes are shown in regard to the failure rate of electrical facilities. By adequately replacing parts and/or conducting partial renovation within the zone of recommended renovation time, stable overall facilities can operate for a longer time.

If the equipment suddenly fails, it is difficult to secure trouble-shooting personnel and there is a risk that it will take longer to repair.

(3) Shortage of skilled engineers

The number of skilled engineers who can assess equipment accurately and quickly decreases annually due to the declining birthrate and aging population.

To address these issues, we have built a sensing system. This is to collect sensor data installed in infrastructure equipment. As a result, we realized further advancement of maintenance inspection work.

3 Sensing System

Fig. 2 shows an example of the sensing system configuration. The sensing system is composed of a Personal Computer (PC), a Power over Ethernet (PoE)-ready switch, a mobile router, and an analog input board. The analog input board is applicable to a variety of input mode like voltage input, current input, and Integrated Electronics Piezo Electric (IEPE). It configures an interface according to the type of sensors.

When a sensor is connected to an Ethernet-ready analog input board, it can be connected to a PC through the PoE-ready switch. The PC then gathers sensor data or analyzes facility status based on the gathered data. The result of analysis is then transmitted to the cloud via the mobile router. **Fig. 3** shows an example of a screen displaying such analysis results via the cloud. As shown in an upper diagram of **Fig. 3**, updated values of various parts in equipment being monitored can be examined in the monitor screen. As shown in a lower diagram of **Fig. 3**, time-serial variations in various sensor data can be checked by examining the trend graph. This sensing system always grasps equipment operating status through continuous gathering of sensor data. By this function, this sensing system can grasp early warning signs of failure and can proactively prevent the occurrence of failure. In addition, the problem of shortage of skilled engineers is solved by incorporating the know-how of skilled engineers into the data analytics.

4 Features of our Sensing System

The sensing system we developed has the following five features.

(1) No need to modify equipment.

When installing equivalent systems in infrastructure equipment, sometimes large-scale modifi-

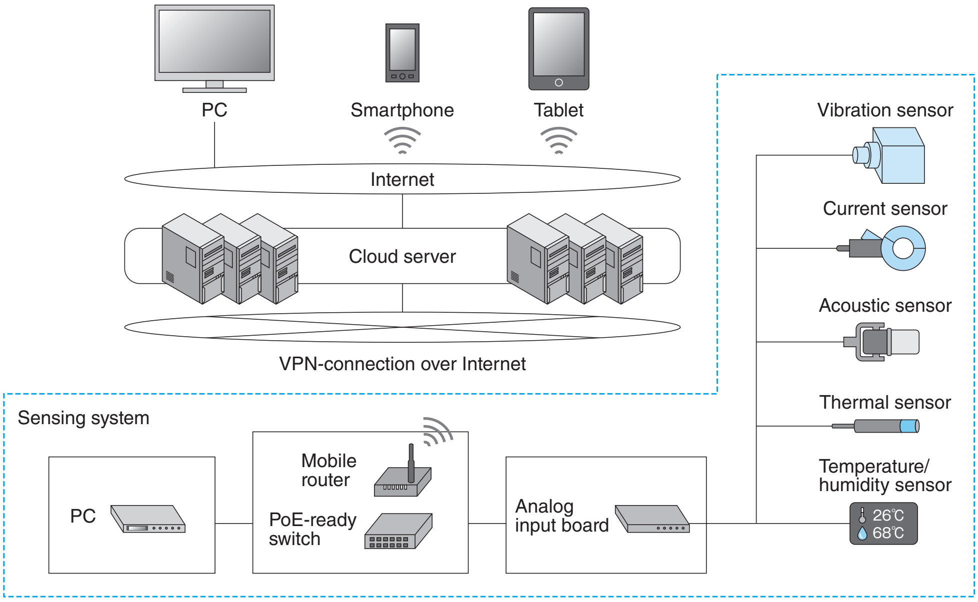


Fig. 2 Example of Sensing System Configuration

Output data from various sensors are analyzed by PC and the analytical results are transmitted to the cloud via a mobile router.

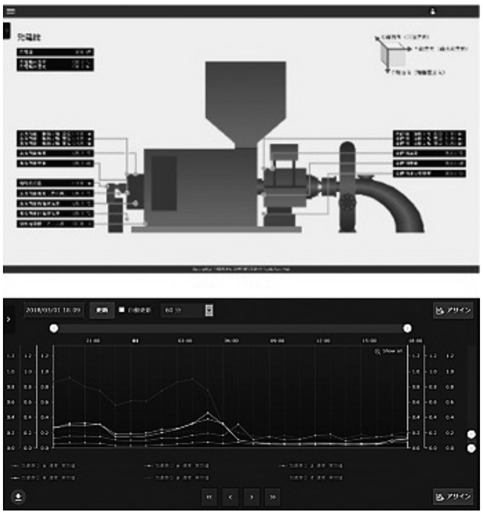


Fig. 3 Example of Cloud Screen

The upper diagram is used to check the latest data from sensors mounted on the designated parts of the target equipment. The lower diagram is used to check time-serial changes in data from various sensors.

cation work to the facility equipment is necessary. In case of the modification of the infrastructure equipment, the work requires the stoppage of the equipment during modification work which can take a very long time. Infrastructure facilities provide lifeline infrastructure for residents, so it is difficult to stop operation for long periods of time. This sensing system consists of equipment surface-attached devices such as sensors on the equipment (see Fig. 2.) There is no need to modify infrastructure equipment when installing such devices as they can be installed without stopping equipment for such durations of time.

(2) Less wiring

Usually an analog input board requires at least two wires for power supply and data communication. It is not always possible, however, to secure a power supply for the analog input board near the equipment to be measured. In this sensing system, a PoE-ready Ethernet cable can be used to feed and communicate with the analog input board with a single cable. In addition, because the PoE can be wired up to 100m according to the IEEE Standard, sensor data can be collected even in an environment where a power source cannot be secured near the measurement target equipment.

(3) System expansion is easy.

Fig. 4 shows examples of sensing system extension. If a sensor is to be added after installing this sensing system in the equipment to be measured, expanding the sensing system is easy by adding an analog input board and sensor and wiring with a PoE cable.

(4) System can be built efficiently.

Sensors used for measurement vary in type and number depending on the equipment to be measured. Normally, the sensing system software must configure a dedicated application for each facility each time. The aforementioned applications

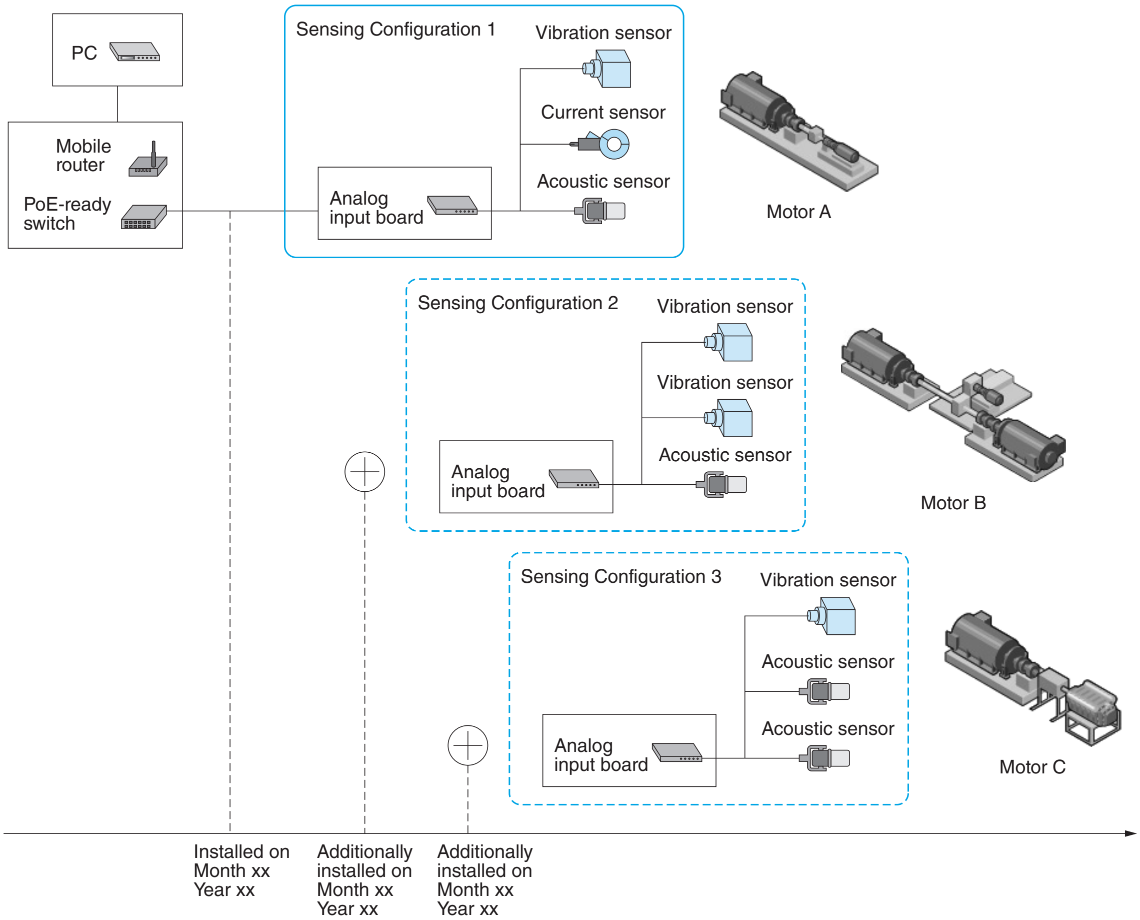


Fig. 4 Examples of Sensing System Extension

This sensing system configuration can be easily extended even after the installation of the system.

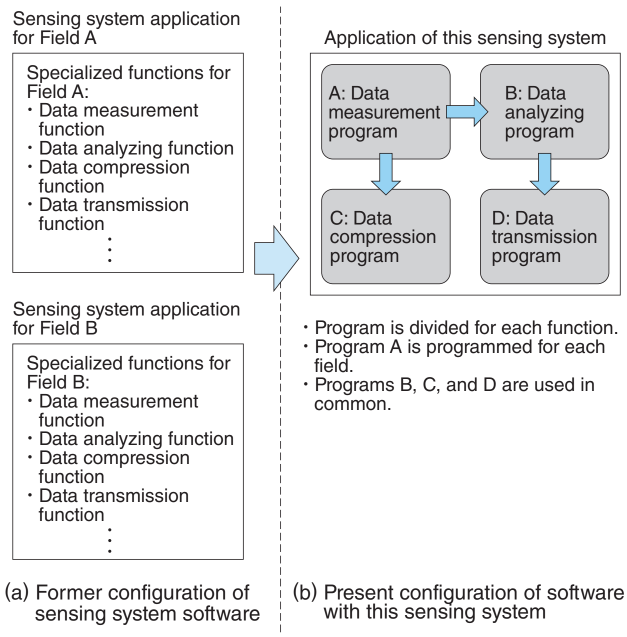


Fig. 5 Software Configuration of our Sensing System

A difference is shown between (a) former configuration of sensing system software and (b) present configuration of software with this sensing system. There is a feature that software programming of this sensing system is possible by simply reprogramming the data measurement program for each target equipment.

must be equipped with data measurement functions, data analysis functions, data compression functions, and data transmission functions specialized for each facility. Building such an application is time consuming.

Fig. 5 shows the software configuration of our sensing system. In order to quickly build applications, the sensing system software programs are divided and configured according to each function. The "data measurement program" needs to change the configuration depending on the sensors used. The "data analysis program," "data transmission program," and "data compression program," however, do not need to be changed and can be commonly used. When the "Data Analysis Program," "Data Transmission Program," and "Data Compression Program" are initially created, these programs can be reused. As shown in Fig. 6, from the second time, the software program preparation period can be reduced to about 1/6.

With the above software, the sensing system can be configured flexibly and in a short amount of time against the sensor configuration for each equipment. As an example, **Fig. 7** shows the difference in the sensing system configuration against the target facilities.

(5) Remote operation is possible.

This sensing system sends the analysis results on the sensor data to the cloud via a Virtual Private Network (VPN) connection over the Internet. As a result, the data sensed from the rotating machine can be easily confirmed from IT devices such as PCs, tablets, and smartphones. In addition, software updates, operation data logs collection, and setting changes on measurement programs can be performed remotely without being onsite. **Fig. 8** shows the remote control function of the sensing system.

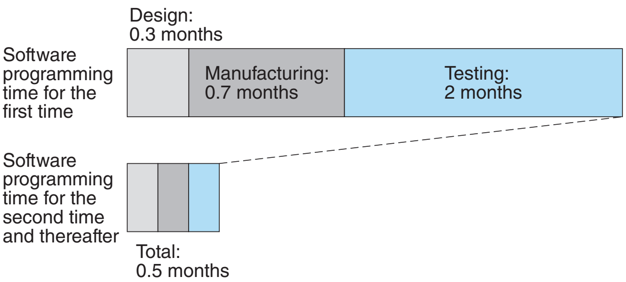


Fig. 6 Software Programming Period for the Sensing System

This sensing system can be programmed in the timely manner by the features shown in **Fig. 5**.

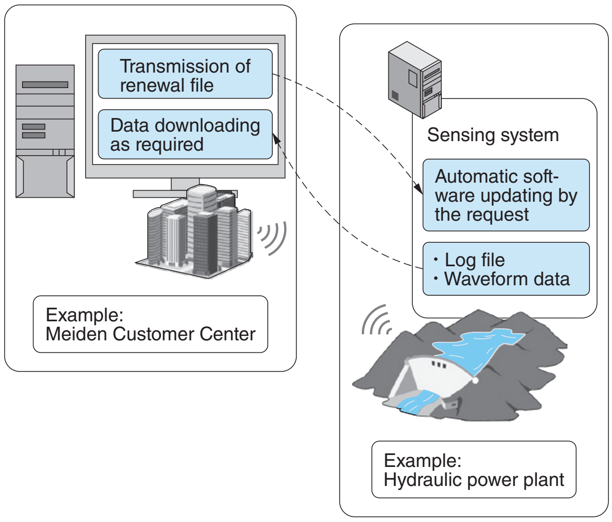
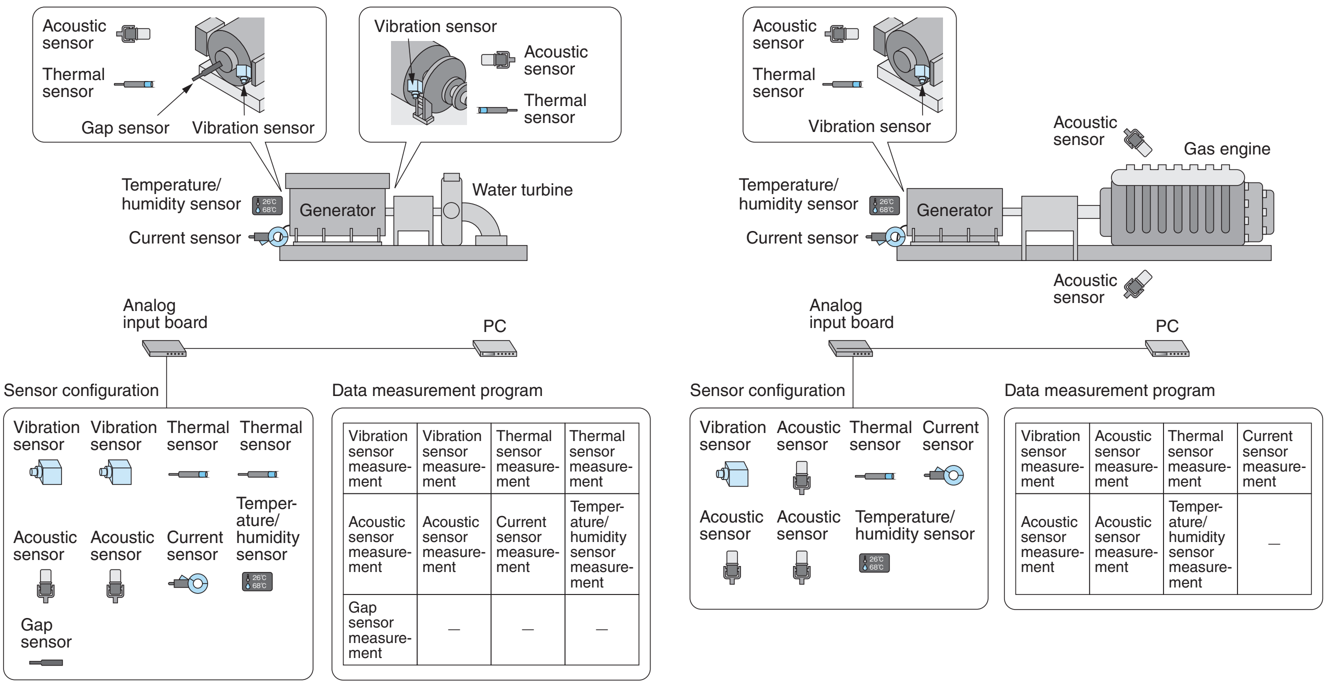


Fig. 8 Remote Control Function of Sensing System

Remote control is possible for software updating to the sensing system, downloading of waveform data or log files from the sensing system.



(a) Sensing system for hydraulic turbine generator

(b) Sensing system for gas engine generator

Fig. 7 Difference in Sensing System Configuration against the Target Facilities

A configuration example of the sensing system is shown for a hydraulic turbine generator and a gas engine generator. According to the type of target equipment, different sensors are installed.

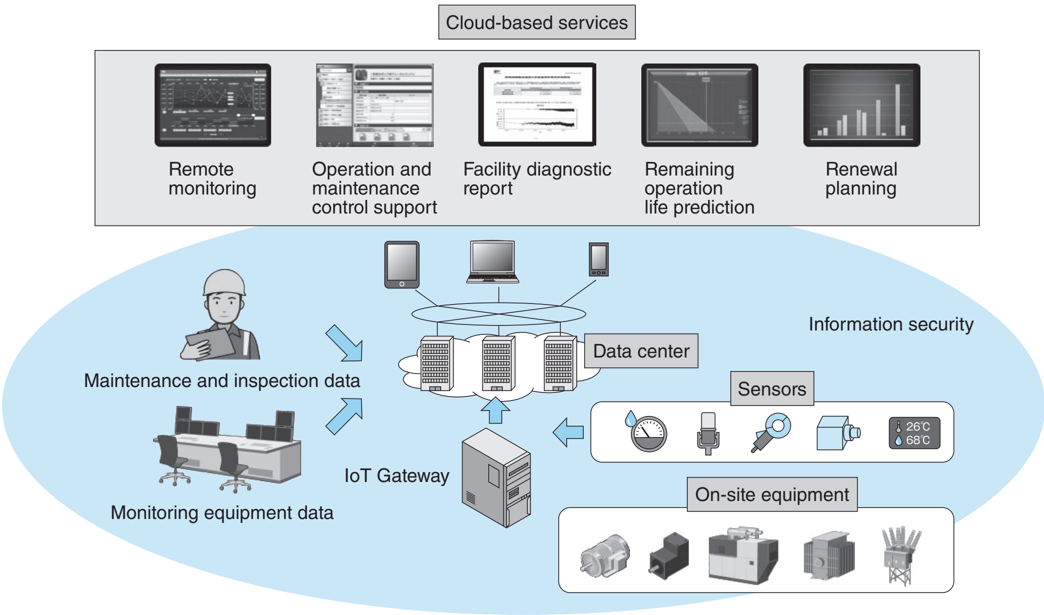


Fig. 9 Example of IoT System Configuration

An example of IoT system configuration using the sensing system is shown.

5 Postscript

This paper introduced our newly developed sensing system for infrastructure equipment. This sensing system has several features: (1) it can be installed quickly and easily on the existing equipment and (2) easy system expansion.

In addition, by building this sensing system, the customers can build Internet of Things (IoT)-based systems for preventive maintenance of the infrastructure equipment as shown in Fig. 9. It enables support to customers such as remote monitoring of equipment, support for operation and drafting facility maintenance plans, equipment diagnosis and prediction of remaining operation life, and drafting facility renovation plans.

Going forward, we would like to contribute to the peace of mind for the people, and safety and stable operation of equipment in the social infrastructure field.

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