Facility Management by IoT (Transformer Remote Diagnosis System)

Koichi Heima,
Yasuhiko Wakabayashi

Keywords IoT, Transformer

Abstract

Through the advancement of technologies relating to cloud computing, smart devices, network, and sensors, the Internet of Things (IoT) is about to become popular. We recently made a transformer remote diagnosis system as an IoT-type monitor service. By mounting various sensors on a power transformer and making it network-ready, the transformer changes to the IoT mode. In so doing, we can grasp the status of power equipment, conduct automatic diagnosis and realize the proper technical support for equipment maintenance and operation. In this fashion, we are improving our technical repair and maintenance control levels.

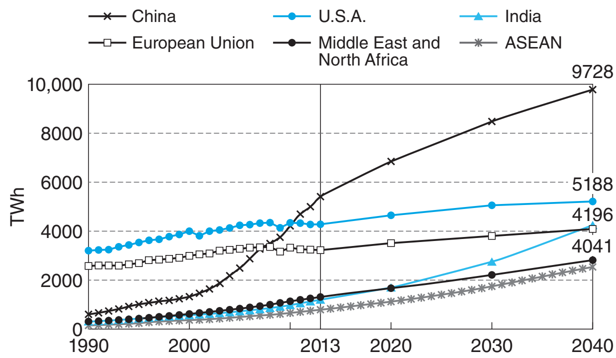
1 Preface

Equipment such as power transformers, circuit-breakers, and switchgears in substation facilities play an important role and functions to determine stability and reliability of power supply. For various fields at home and abroad like power utilities, government and public sectors, and the rail sector, we have supplied many power Transmission and Distribution (T&D) products and systems to help improve society infrastructure.

In Japan, many power transformers (one of T&D products) have been operating for more than 30 years; such long-running power products are increasing. Under such circumstances, it is vital to promote facility renovation seamlessly while also conducting adequate facility management and taking measures to proactively prevent failures.

At the same time, the demand for electricity is rapidly increasing worldwide, partly because of sharp population growth in developing nations and the expansion of the economic scale. Fig. 1 shows global power demand prediction. To realize well-run power network systems and secure quality power, it is essential to keep T&D products up and running and conduct proper repairs and maintenance to them.

It is required to apply auto-analysis and diagnosis results based on the Internet of Things (IoT) data to asset management and repair and maintenance management systems so that we can build more efficient management systems.



Source: 413th Forum on Research Works "Asia/World Energy Outlook 2013 –Analyzing Changes Induced by the Shale Revolution–" (The Institute of Energy Economics, Japan)

Fig. 1 Grobal Power Demand Prediction

Demand for electric power tends to increase all over the world.

This paper introduces our cloud-based monitoring services used in IoT technology developed for a solution to the aforementioned issues.

2 Transformer Remote Monitoring and Diagnosis System Configuration

Fig. 2 shows a configuration of transformer remote monitoring and diagnosis systems utilizing cloud-based monitoring services connecting the IoT devices. Fig. 3 shows a screen example of the transformer remote monitoring and diagnosis system. The data acquired by the sensors that

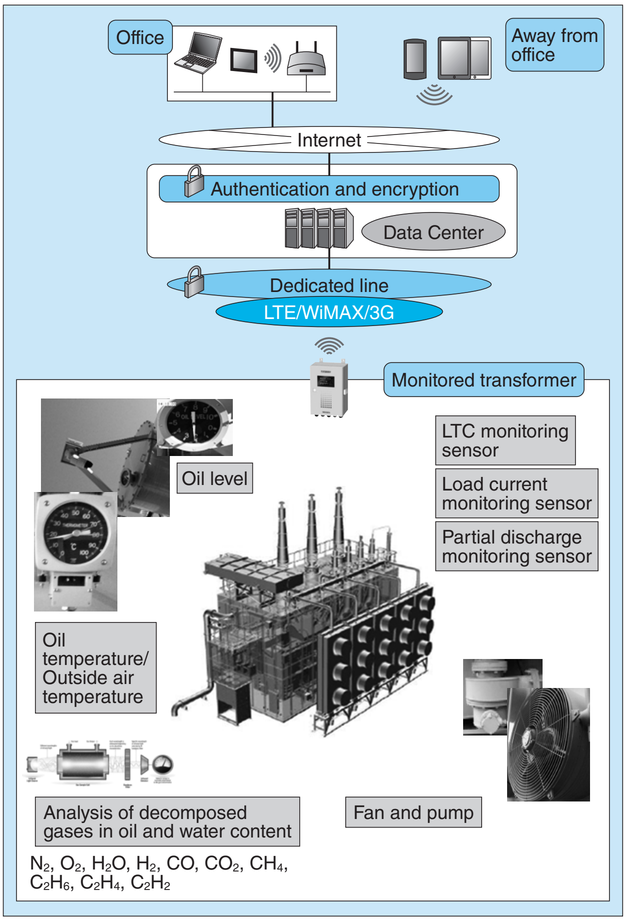


Fig. 2 **Configuration of the Transformer Remote Monitoring and Diagnosis Systems**

This shows the system configuration. Various sensors are mounted on the transformer tank and data from these sensors are uploaded and transferred to the cloud computing system via mobile phone network. The customers can access such information via the Internet.

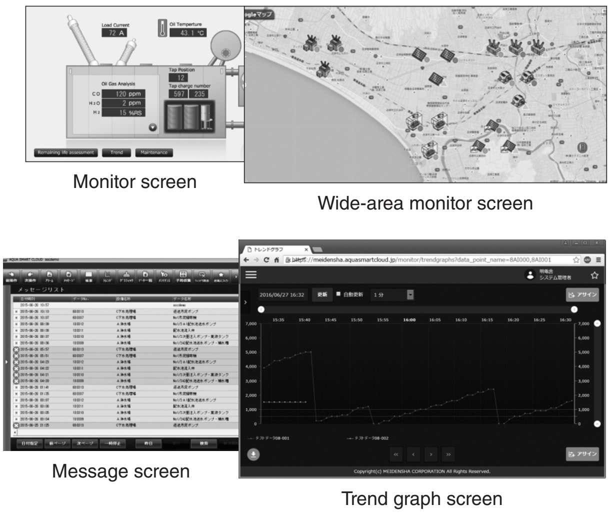


Fig. 3 **Screen Example of the Transformer Remote Monitoring and Diagnosis System**

The screen configuration for displaying information from each monitoring screen of the cloud and sensors attached to the transformer is shown.

are mounted on the transformer tank are uploaded to the cloud computing system via mobile phone network. We monitor the conditions of transformer operation using these data. At the same time, the data accumulated on the cloud system are analyzed. Under the cloud-based monitoring services, the following are monitored: outside air temperature, oil temperature, oil level, load current, tap position, fan vibration, pump vibration, gas ingredients in oil, and partial discharge. The items diagnosed are transformer modal judgment and estimating of remaining useful life of transformers, fans, and pumps.

When cloud-based monitoring services are introduced, the repair and maintenance of the transformer can be changed from Time Based Maintenance (TBM) to Condition Based Maintenance (CBM). In case of TBM, inspection, repair and parts replacement are carried out at the specified intervals. In CBM, repair or parts replacement can be made only on the problematic area before the failure takes place since the equipment conditions are constantly monitored and we can identify the state of deterioration and the potential problem area. Since CBM can detect a sign of facility deterioration in advance, adequate measures can be taken. The benefits are reduction of failure rate, improvement of facility reliability, and reduction of maintenance costs. As a result of continuous monitoring, we can precisely determine the aging level of power equipment. In addition, a definitive time guideline can be determined for facility renovation.

3 Features of the Transformer Remote Monitoring and Diagnosis System

Features of this system are itemized below.

(1) Custom installation is possible independently of existing aged facilities.

(2) System configuration has excellent environment-resistant feature (ambient temperature: −10～60℃).

(3) Communication cabling can be decreased by using wireless network system.

(4) According to the facility conditions and the adopted repair and maintenance system, the monitored items can be changed.

(5) It can save labor of daily patrol inspection.

(6) Automation of residual lifetime diagnosis is possible for aged facilities. It is possible to provide asset management support by giving a degree of renovation priority among them.

(7) Maintenance-related data acquired in the past can be uploaded to the system database.

4 Transformer Monitoring Items

Fig. 4 shows a transformer monitor screen. Table 1 shows the transformer monitor levels and monitoring items. The transformer monitoring items can be selected as small scale or large scale according to the transformer size.

4.1 Monitoring of Oil Level, Oil Temperature, and Tap Position

Mechanical meters and indicators like oil level gauge and thermometer mounted on the transformer tank are equipped with intelligent cameras. The images of these meters are uploaded and the analog image data are converted into numeric data by using image recognition technology. Only the numeric data can be transferred to the cloud system. Fig. 5 shows how an intelligent camera takes an analog image of an oil level gauge.

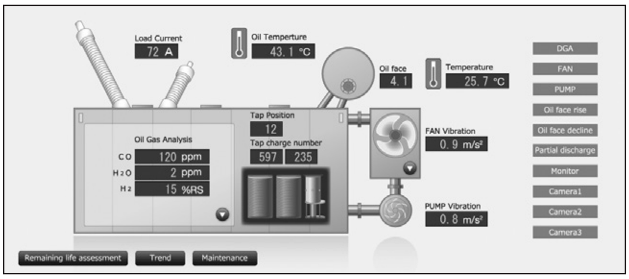


Fig. 4 Transformer Monitor Screen

A screen configuration is shown where information from the sensors mounted on the transformer is displayed.

Table 1 Transformer Monitor Levels and Monitoring Items

The monitoring items for each transformer size are shown.

Monitoring items		Small-sized transformer	Large-sized transformer
Outside air temperature		○	○
Oil temperature		○	○
Oil level		△	○
Load current		○	○
Tap	Position		△
	No. of operations		△
Fan vibration		△	△
Pump vibration		△	△
Partial discharge		△	△
Insulation oil	H_2, H_2O, CO, CO_2		○
	O_2, N_2, C_2H_2, C_2H_4, CH_4, C_2H_6		○
Residual lifetime diagnosis	Fan remaining useful life	△	△
	Pump remaining useful life	△	△
	Transformer modal status judgment		△
	Transformer remaining useful life judgment	△	△

○: Standard △: Optional

4.2 Gas Analysis in Oil

Insulation oil is used for the insulation and cooling of power equipment. If unusual overheating and/or insulation deterioration is caused inside the equipment, decomposed gases and degradation product are dissolved into insulation oil. Table 2 shows the relationship between generated gases and classification of an abnormality. We analyze the decomposed gases in oil and identify the abnormality. In so doing, we take necessary measures enabling us to maintain transformer performance. In the conventional method, we conduct gas analysis in oil at the interval of several years. For this time system, we can automate gas analysis in oil and prevent the occurrence of a failure in advance by detecting abnormality before the failure occurs. At

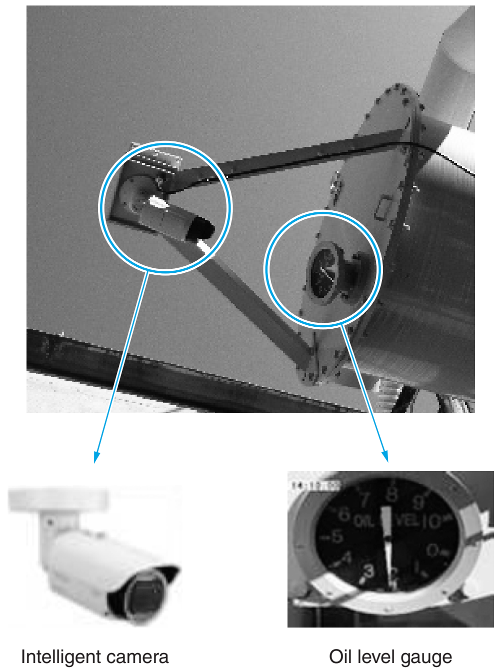


Fig. 5 How Intelligent Camera Takes Analog Image of Oil Level Gauge

A view of the system is shown, where analog measured data of the oil level gauge is captured by an intelligent camera and then converted into numerical data. The obtained data are converted from analog to digital data by using image recognition technology.

Table 2 Relationship between Generated Gases and Classification of Abnormality

Types of abnormality judged by decomposed gases are shown.

Types of abnormality	Major decomposed gases						
	CO	CO_2	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6
Insulation oil over-heating	—	—	○	◎	—	◎	○
Insulation overheating in each oil-immersed component	◎	◎	○	◎	—	◎	○
Discharge in insulation oil	—	—	◎	○	◎	○	—
Insulation discharge in each oil-immersed component	◎	◎	◎	○	◎	○	—

◎: Featuring gas, ○: Related, —: Not related
Note: The graph is made on the basis of Table 4-1-1 of "Maintenance Management for Oil-Immersed Equipment by Gas Analysis in Oil" (Electric Technology Research Association) released for the Electric Technology Joint Research Vol.36, No.1.

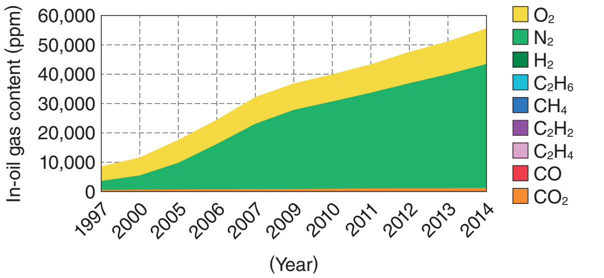


Fig. 6 Integration Graph of Decomposed Gases in Oil

Secular variations in in-oil gas content are shown.

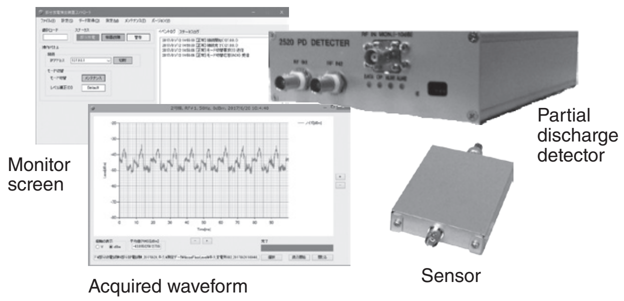


Fig. 7 Partial Discharge Detector and Monitor Screen

External appearance of partial discharge detector and sensor plus monitor screen and acquired waveforms are shown.

that time, we conduct a diagnosis of remaining useful life based on trend analysis. Fig. 6 shows an integration graph of decomposed gases in oil.

4.3 Partial Discharge

The occurrence of partial discharge is monitored by using a partial discharge detector with a Transistor Earth Voltage (TEV) sensor. When a partial discharge occurs, a potential difference is generated by the effect of a creepage current that flows along the casing surface and the potential difference is detected. Fig. 7 shows a partial discharge detector and monitor screen. It is then possible to acquire waveforms of partial discharge.

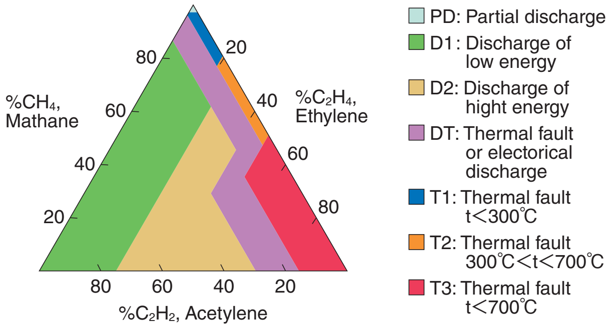


Fig. 8 Duval Triangle

Transformer modal judgment by the composition ratio of the gases in oil are shown.

5 Transformer Diagnostic Functions

The transformer diagnostic functions include the items of transformer modal judgment and estimating of remaining useful life of transformers, fans, and pumps.

5.1 Transformer Modal Status Judgment

Fig. 8 shows the Duval Triangle. Based on the result of gas analysis in oil, the transformer modal status is identified in conjunction with the Duval Triangle. According to the contained amount of CH_4, C_2H_4, and C_2H_2, the identified modal status such as partial discharge and overheating is displayed in a graph.

5.2 Diagnosis of Transformer Remaining Useful Life

For the diagnosis of transformer remaining useful life, the concentration of CO and CO_2 gases measured as a result of gas analysis in oil and years of transformer operation plus average load factor are examined. We then conduct compensation for the water content and make correction on the oil deterioration prevention system. Overall remaining useful life estimate is then made and the results are displayed in a graph. Fig. 9 shows a graph example of a diagnosis of a transformer's remaining useful life.

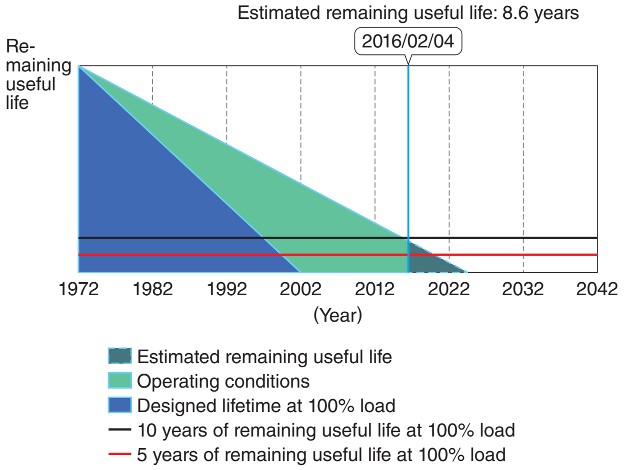


Fig. 9 Graph Example of Diagnosis of Transformer's Remaining Useful Life

The remaining useful life is computed by using the diagnosis of a transformer's remaining useful life.

6 Postscript

The technology for diagnosis of a transformer's remaining useful life is still under development. We aim to advance the accuracy level by accumulating the large volume of data of operation, improvement of analytical technology, and the development of new sensors. At the same time, we will try to expand the application to other T&D facilities such as switchgears and lightning arresters.

- This IoT-based Remote Diagnosis System uses some technology under license from Central Research Institute of Electric Power Industry (CRIEPI), Japan.
- All product and company names mentioned in this paper are the trademarks and/or service marks of their respective owners.