Introduction of Small-Scale Hydropower Generation Control System Using Cloud System

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Keywords Small-scale hydropower generation, ICT, Cloud, IoT, Patrol inspection support

Abstract

Responding to the expansion of small-scale hydropower generation and the demand for more sophisticated and smarter maintenance of hydropower plants in Japan, we built a small-scale hydropower generation control system using our cloud system, "AQUA SMART CLOUD (ASC)".

By applying a cloud system, accumulated data can be accessed from anywhere, and the data (condition changes, failures, and measured values) stored in the Programmable Logic Controller (PLC) inside generator control panel can be provided as chronological data.

Data from multiple hydropower plants can be checked on a single monitoring screen. As such, video monitoring cameras can be installed inside the hydropower plant and in the upper water tank, making it possible to check the status of the power plant without going to the site.

In this way, the hydropower generation control system can go smart by utilizing chronological data.

1 Preface

Hydropower generation in Japan has a long history, dating back more than 100 years with many hydropower plants built across the country. Hydropower has recently been attracting attention as a sole domestically produced renewable energy resource that does not emit CO_2 during the power generation process. It is a key power resource for realizing a carbon-neutral society.

There are, however, some related concerns: (1) the rising importance of maintenance because of aging equipment, (2) the need for remote monitoring due to the fact that many hydropower project sites are located in mountainous areas, and (3) the issue of passing on skills and know-hows of aged operating engineers to newer generations. Given these issues, there is a need for hydropower plants to receive more sophisticated and smarter maintenance service plans that utilize Information and Communication Technology (ICT) and the Internet of Things (IoT). Furthermore, the Ministry of Economy, Trade and Industry of Japan formulated the "Smart Maintenance Action Plan" in April 2021, and it is anticipated that the plan will accelerate more advanced and smarter maintenance for hydropower plants.

This paper introduces a small-scale hydropower generation control system that we built to meet the demand for more sophisticated and smarter maintenance of hydropower plants.

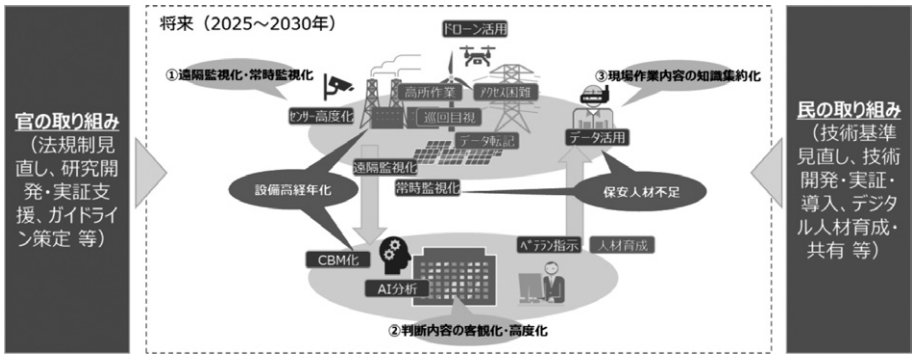
2 Smart Facility Maintenance Action Plan

This plan, formulated by the Ministry of Economy, Trade and Industry of Japan, aims to promote reliable technology implementation with a future vision of achieving both maintenance and productivity improvements in electrical facilities.

Fig. 1 shows the future image of electrical facility maintenance going smart. The action plan sets 2025 as a target year for the future of smarter maintenance service for hydropower generation facilities and aims to achieve the following.

(1) Aim to rationalize facility maintenance costs by further increasing the sophistication of remote monitoring and reducing inspection time. It also promotes the development of useful but not currently established technologies.

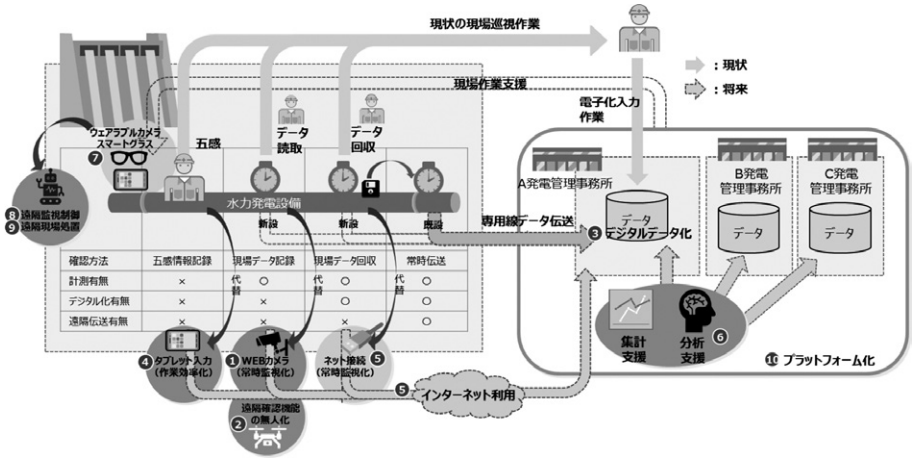
(2) Through the use of smart technology, we aim to improve facility maintenance capabilities and



Source: “Action Plan for Electrical Facility Maintenance Going Smart” (Ministry of Economy, Trade and Industry)

Fig. 1 **Future Image of Electrical Facility Maintenance Going Smart**

A future image of electrical facility maintenance going smart is shown.



Source: “Guidelines for Introducing Smart Technology for Maintenance Management Operations in hydropower systems”

Fig. 2 **Example of Facility Management Work for Hydropower Systems**

An example of maintenance management work for hydropower systems before and after the facility goes smart is shown.

accurately identify signs of abnormalities, contributing to planned maintenance and reducing unplanned shutdowns.

Additionally, guidelines for the introduction of smart technology that utilizes ICT for hydroelectric power generation were issued in April 2022. **Fig. 2** shows an example of facility management work for hydropower systems before and after going smart. This guideline describes support for the introduction of smart technology for the following purposes, and introduces examples of actual demonstration implementation.

(1) By introducing smart maintenance into facility management operations, we are accumulating data by digitizing information that was previously acquired through the five senses and analog methods, and improving the level of maintenance control by using analysis technology such as Artificial Intelligence (AI).

(2) By developing a platform that connects digitized data via a network, we will make the remote monitoring work possible “at any time” and “from anywhere”. We will develop “remote monitoring and constant monitoring (rationalization of inspection frequency)” .

(3) In response to the issues of the aging equipment, we will use AI and other tools to make upgrade or repair decisions in a more objective and sophisticated manner.

(4) Decreasing the number of facility management personnel will lead to efforts in passing on skills and know-hows by consolidating knowledge of field work through digitalization.

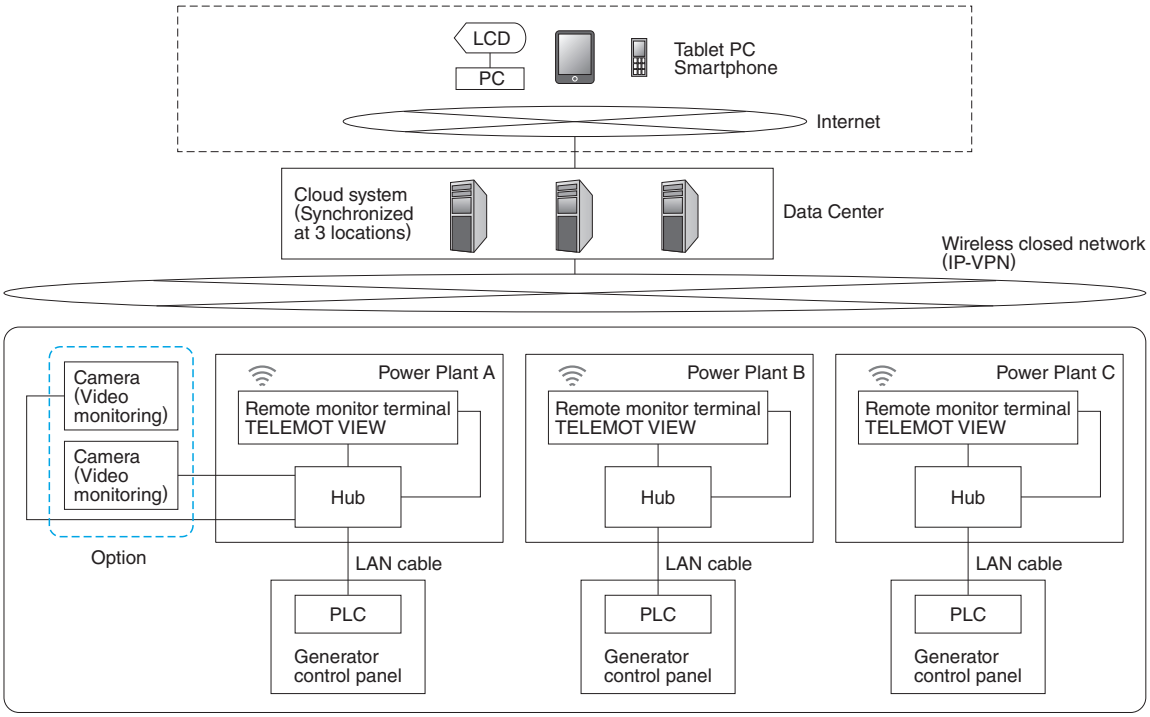


Fig. 3 Telecommunication System Configuration

The PLC and TELEMOT VIEW are connected with a LAN cable through a hub. Data transmission is conducted from TELEMOT VIEW to the Cloud and data is monitored through Internet.

3 System Configuration

In order to implement the action plans and guidelines of the Ministry of Economy, Trade and Industry of Japan, we constructed a small-scale hydropower generation control system that utilizes our cloud system, “AQUA SMART CLOUD (ASC)”. Fig. 3 shows the telecommunication system configuration. This system aggregates data from not only one hydropower plant, but multiple hydropower plants in the cloud, and allows for checking it on a single monitoring screen. At each hydropower plant, a Local Area Network (LAN) cable connects the cloud communication terminal called “TELEMOT VIEW” and the Programmable Logic Controller (PLC) inside the generator control panel. Since TELEMOT VIEW and the cloud can be connected wirelessly, data can be easily transmitted to the cloud without the need for major construction work such as connecting the hydropower plant and control center with communication lines. All data held by the PLC (condition changes, failures, and measured values) is transmitted to the cloud, where it is accumulated and saved every minute. The accumulated data can be viewed on general-purpose PCs, tablet PCs, and smartphones. Fig. 4 shows the external dimensions of TELEMOT VIEW.

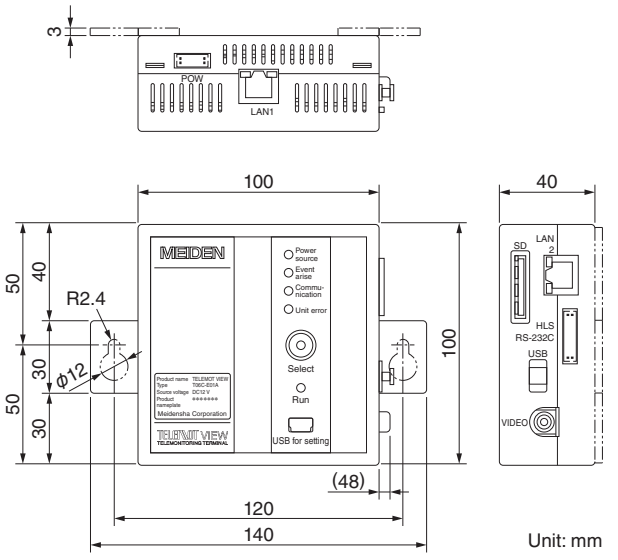


Fig. 4 External Dimensions of TELEMOT VIEW

External Dimensions of TELEMOT VIEW is shown. It is a compact design with W100 × H100 × D40 mm.

4 Cloud Functions

4.1 Telemetry Data Browsing Function

Accumulated measurement data can be viewed using a cloud wide-area monitoring service using a web browser or a cloud-dedicated app.

Table 1 Overview of Screen Display Functions in Wide-Area Monitoring Services

Overview of screen display functions in ASC wide-area monitoring services is shown.

Function	Contents
Graphic	The current status of plant facilities is examined in visual expression. Equipment conditions and telemetry values are indicated in symbol colors, figures, and graphic variations.
Trends	Trend data are checked with line graphs and bar charts. Recent and past trends can be observed and saved in files.
Data list	Present status of plant facilities can be indicated in lists. Equipment conditions and telemetry values are displayed in status names and figures.
Messages	Information about operation, malfunction, errors, systematic performance, and equipment functions in the plant composing equipment units is displayed in a list. Past message browsing and file stowage are possible.
Alarm	Information about malfunction and errors in plant composing equipment units as well as telemetry equipment is displayed in a list. In the event of an alarm, both alarm sound and alarm prompt are generated.
Ledgers	Daily, monthly, and annual reports can be displayed and printed out. Past ledger browsing and file stowage are possible.
Maintenance	Monitor levels for malfunction and errors plus customer data can be preset. Updated application loading is possible. For each customer, limitations for equipment usage permission can be set.
Follower station data logging	For a specific follower station, telemetry and transmission period can be hastened for the specified duration.
Favorite	By the registration of often-used screens, the same screen can be called up by a simple key touch.
Present value acquisition	A present value is acquired by making data gathering once from a follower station.

Table 2 Overview of Facility Management Servicing Functions

Overview of ASC facility management servicing functions is shown.

Function	Contents
Facility ledger	Registration and browsing of facility equipment ledgers (type of works, installation place, installed year and month, manufacturer, type, serial number, lifetime, acquisition price, etc.)
Document management	Registration and browsing of facility equipment manuals, drawings, and complete book in electronic files Registration in relation to the respective functions (Equipment ledger, equipment management, inventory control) Retrieval by equipment types and keywords
Inspection plan	Scheduled inputting of inspection schedule based on each inspection table Browsing and amendment of inspection result
Inspection record	Inspection result inputting in the scheduled order per inspection table Off-line operation of tablet enabled for patrol inspection Photo registration and comment inputting enabled during inspection Inputting of inspection exclusion enabled in the event of no inspection
Inspection compilation	Registration of inspection items combined with customer's Excel type
Inspection ledger output	Inspection ledger outputting to customer's Excel type format
Career control	Registration and browsing of machine-based career maintenance and failure information
Inventory control	In-out warehousing and inventory for spare parts, etc.
Work ledger	Registration and browsing of work-related information such as renewal work and overhauling
Location	Browsing of screens established by drawing on the site
Maintenance project	Establishment and browsing of maintenance project

Table 1 shows an overview of the screen display functions in the wide-area monitoring service. The accumulated data can be checked as a trend graph at any set period or cycle. Additionally, daily and monthly reports can be automatically created using data stored in the cloud. Note that daily and monthly reports can be created in any format to suit each customer's operation and inspection standards for each hydropower plant.

4.2 Walkaround Inspection Support Function

The cloud has an inspection support function that uses tablet PCs and other devices for facility management services. By using this function, it is possible to provide a walkaround inspection support function aimed at increasing the efficiency of walkaround inspections at hydropower plants. Table 2 shows an overview of the facility management service functions. By converting the walkaround inspection form (paper) into data and registering it in the inspection support function, walkaround inspection can be performed using a tablet PC. The input data is registered in the cloud as electronic data, and it can output walkaround inspection records in the same previous format. Furthermore, when inspecting by the tablet PC, the current values of the measurement data uploaded to the cloud are reflected in the automatic acquisition function, reducing input work.

4.3 Fault Monitoring Function

Table 3 shows the cloud-based fault monitoring functions. Conventional remote monitoring equipment has a limited amount of data that can be transmitted, and all failure data cannot be transmitted. In the cloud, all failure data, condition changes, and measurement data can be checked, greatly contributing to initial response and root

Table 3 Fault Monitoring Functions for Wide-Area Monitoring Services

Fault monitoring functions for ASC wide-area monitoring services are shown.

Function	Contents
Equipment fault monitoring	Regarding process equipment fault information, alarm sounding, alarm window display, and data stowage into message files are carried out.
Upper/lower limit deviation monitoring	Regarding the preset upper/lower limit values, alarm sounding, alarm window display, and data stowage into message files are carried out based on deviation-related information of the process data.
Signal source error monitoring	Based on signal source error information of the process data, alarm sounding, alarm window display, and data stowage into message files are carried out.
Rate of change error monitoring	Based on rate-of-change error information of the process data, alarm sounding, alarm window display, and data stowage into message files are carried out.
Alarm prompt display	In the event of detection of aforementioned errors, automatic display of alarm window is carried out as an alarm prompt.

cause investigation. Additionally, upper, and lower limits can be set for the measured data, and an alarm will be sent if the data deviates from these limits. By effectively utilizing this function, it is possible to understand behavior before a failure occurs, leading to early detection of possible failures.

4.4 Video Monitoring Function

When managing and operating a hydropower plant, it is essential to prevent clogging of garbage in the outdoor upper water tank, and regular visual checks are required. Using a cloud video monitoring service, we built a system that allows visual confirmation without having to go directly to the site. Table 4 shows an overview of the video surveillance service functions. In addition to being able to check the current live scene remotely, it is also possible to display previously recorded video and perform camera operations such as changing the camera direction and zooming.

5 Application to Existing Hydropower Plants

At many hydropower plants, data used to control hydropower generation facility (rotational speed, generator output, etc.) is imported into the PLC inside the generator control panel, but some mechanical measurement items such as bearing temperature, runner back pressure, etc. are handled only by using analog meters. Data deemed necessary for advanced maintenance will, therefore, be replaced with meters that can output analog data so that they can be imported into the PLC. In some cases, measures such as adding sensors as necessary is required. Table 5 shows examples of measurement items.

The data collected in the PLC is transmitted from TELEMOT VIEW to the cloud. TELEMOT VIEW is compact and does not need to be housed inside a switchgear, so it can be used even in a hydropower plant where installation space is limited.

Table 4 Overview of Video Surveillance Service Functions

Overview of ASC video surveillance service functions is shown.

Function	Contents
Video display screen	The main screen displays the camera images. The displayed camera images are updated at each acquisition period of video images from each camera.
Camera menu	Camera images are manipulated. Images from each camera are displayed on the screen.
Registration and display of the display pattern	For camera image allocation patterns on the screen, patterns can be registered, deleted, and called up.
Auto-playback of display patterns	Registered display patterns are automatically displayed on the screen.
Camera control	Camera's direction, zooming, and other performance can be controlled.
Retrieval, display, protection, and saving (download) of past images	Recorded past images can be displayed, protected, deleted, and saved (download).
Camera setting	Camera information setting, home position, and preset position can be registered.
Record setting panel	Recording method for camera images is set.

Table 5 Measurement Items for Hydropower Plants

An example of measurement items for a hydropower plant is shown. There are two item groups: (1) measurement items used for the control of power generating facilities and (2) measurement items for monitoring only.

No.	Contents	No.	Contents
1	Generator output	11	Flow rate
2	Generator voltage	12	Penstock pressure
3	Generator current	13	Runner back pressure
4	Generator frequency	14	Draft hydraulic pressure
5	Generator power factor	15	Drive-side bearing temperature
6	Revolving speed	16	Anti-drive-side bearing temperature
7	GV aperture	17	Drainage channel water level
8	Tank water level (upper stream)	18	Outdoor temperature
9	Tank water level (lower stream)	19	Indoor temperature
10	Output power		

6 Postscript

We believe that a small-scale hydropower generation control system can greatly contribute to the advancement of maintenance at hydropower plants.

We will continue to incorporate various requests from customers and contribute to the sustainability and improvement of the hydropower generation business.