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Operational Evaluation of Self-powered Landslide Disasters Monitoring System

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Abstract– In recent years, landslide disasters caused by localized torrential rain have damaged seriously in Japan. We built a monitoring system to suppress damage caused by landslide disasters, and started operation in May 2015.

In the past, we tried to model operational availability of the system, and clarified the requirement to achieve 100% availability. After that, the operation of the new system satisfying the requirement was carried out from November 2016, and we evaluated the actual operational data.

In the evaluation as of May 2017, the system achieved 100% availability. Moreover, we showed the practicality of modeling the system in the mountain.

1. Introduction

In recent years, landslide disasters caused by localized torrential rain have damaged seriously. In Japan, steep terrain is widely distributed, and there are about 520 thousand dangerous areas of landslide disasters [1]. Also in Hiroshima City where Hiroshima City University (HCU) is located, large-scale disasters occurred on August 20, 2014 [2], and on June 29, 1999[3], and have damaged seriously so far. Because it is difficult to predict natural phenomena, there has been a growing demand for monitoring landslide disasters in real time [4, 5]. When residents can gather occurrence information of landslide disasters in real time, they can evacuate at an appropriate timing. Therefore, we built a self-powered monitoring system for the purpose of continuous operation for 24 hours, which can monitor dangerous areas in real time.

The monitoring system was set up at 6 locations where it is predicted the risk of landslide disasters in Hiroshima City (*Saeki-ku Kouchi, Asaminami-ku Yagigaoka, Asaminami-ku Midorii, Asakita-ku Toge, Asakita-ku Nabara, Asakita-ku Yamakura*). Operation of the first system started from May 2015. In the operation of the system with the power consumption of 7 W at first, there was a problem that the availability rate did not become 100% in each district. Therefore, in this study we modeled the system availability by considering the operational experience (sunshine duration, weather condition, charge efficiency), and clarified the requirement of 100% availability.

From November 2016, we installed a 5W new system that achieves the requirement and started operation.

In this paper, we show the results of operation and achievement of 100% availability from the evaluation.

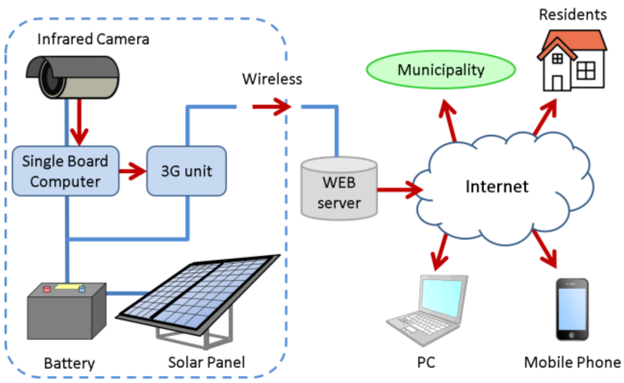

Fig.1. Monitoring system configuration

2. Outline of monitoring system

Fig.1 shows the configuration of the monitoring system constructed in this study. This system has two 100 W solar panels for power supply in order to operate even in the place that cannot be secured commercial power supply. Also, it has an infrared camera to take image data continuously day and night. Raspberry Pi (single board computer) is used for the control unit. At the beginning of installation, we used a wireless router as wireless communication unit, but in order to reduce power consumption, the system has 3G wireless module. The total power consumption of this system is 5 W. The power consumption per day can be estimated as 5 W × 24 h = 120 Wh. Therefore, if the sunshine time is 1.2 hours, the amount of electricity can be supplied for one-day operation, even if the power generation efficiency is 0.5. The storage capacity of the battery is 1,380 Wh. Continuous operation time without sunshine can be derived as 1,380 Wh / 120 Wh/day ≈ 11 days.

By uploading images taken by the camera to the web server of our university at regular intervals, residents can view the images from the web pages.

This system adopts SSH port forward technology, and the administrator can securely connect to a single board computer by using the port set by SSH or VNC application. By using an encrypted communication channel tunneling from administrator to SSH server and from SSH server to the computer, high security remote control can be realized.

Fig.2. Web page of system location map

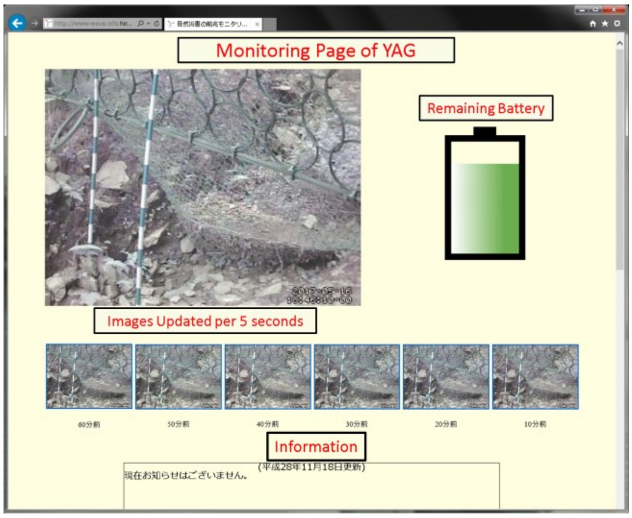

Fig.3. Web page of YAG

3. Outline of image delivery web page

Fig.2 shows a web page with a map of 6 locations where the system is installed. Each distinct has risk of landslide disaster and is designated by Hiroshima City. By placing the cursor on the circle indicating each area in the figure, a preview of the image of the area is displayed at the upper left. By clicking on that circle, residents can access the image delivery page of each area. The positional relationship between HCU and YAG, evaluated in this study is indicated by arrows in the Fig.2.

Fig.3 shows an image delivery web page of YAG. It is displayed a captured image, remaining battery level, information, and images at 10-minute intervals in the past one hour so that we can confirm the state of the time series change.

Residents can browse real-time images by accessing web pages from browsers of terminals owned by them.

The image is automatically uploaded to the web server in our university by using 3G wireless network. The image pixel is 320 × 240 px, and the image size is about 20 kB. It is possible to capture a higher-definition image, though, it takes several seconds to transmit one image because the communication speed is relatively low, on the order of 100 kbps. In this system, we focused on the real-time nature and set the refresh interval to 5 seconds in order to make it easier for the residents to catch the image change.

Each image also shows the captured time, and it takes about 15 seconds from capturing until the image is displayed on the web page because of capturing time, transmission processing, communication transmission delay, display processing.

When the captured image is no longer updated, the image showing stopping will be displayed automatically.

In addition, when the system stops for other reasons, we will display the notification in the information.

4. System operation status

Fig.4 shows the operation status for two years from June 2015 to May 2017 in YAG. The horizontal axis represents time, the vertical axis represents month and day, and the time zone when the system was shutdown due to insufficient sunshine is colored and displayed.

At the beginning of the system installation, we started operation with one 100 W solar panel and 7 W consumption system. However, system-down frequently occurred due to insufficient sunshine in mid-June of 2015 which is the rainy season. After that, we added extra 100 W solar panels. During the winter months from November to February, we experienced system-down from midnight to morning due to the shortage of sunshine as well. We also experienced system-down in 2016 rainy season as well. In September 2016 the system was shutdown by insufficient sunshine due to typhoons.

However, in sunny weather, when the solar panels generated electricity in the morning, we confirmed that the system was starting to operate automatically. Immediately after starting up the system, it uploaded the captured image and confirmed that was resume image delivery on the web.

On November 3, 2016, we set up a new system with power consumption 5W explained in Chapter 2. From then on, stable operation continues without system-down due to insufficient sunshine.

5. Simulation of remaining battery

In this research, we simulate the remaining battery of the current system based on the weather data of the sunshine hours obtained in the meteorological observatory of Hiroshima City [6], and reproduce the operating situation of the monitoring system actually installed.

In this simulation, we calculated the sequential remaining battery amount C_b per an hour at the elapsed time i from the operation by using the following formula

$$\begin{cases} C_b[i] = C_{b\_max} & (C_b[i] \geq C_{b\_max}), \\ C_b[i] = C_b[i-1] + kP_sR_s - P_0 & (0 \leq C_b[i] < C_{b\_max}), \\ C_b[i] = 0 & (C_b[i] < 0). \end{cases}$$

where, $C_{b\ max}$ [Wh] is the upper limit of the battery charge amount, k is the adjustment coefficient, P_s [Wh] is the theoretical value of the one hour power generation amount by the solar panel, R_s is the sunshine ratio per one hour, P_0 [Wh] is the power consumption per one hour of the system[7]. Adjustment coefficient k is a value that depends on power generation efficiency due to seasonal difference in south middle altitude and charge efficiency of charge controller. In this research, in order to make the system unavailability rate during simulation the same as the actual system availability, we determined the value of k on a monthly basis.

Fig.5 shows the image obtained by photographing the sky using a fisheye lens from the YAG system location. The image also shows the locus of the sun during the spring equinox, summer solstice, autumn equinox, and winter solstice. Since the system is installed in the mountains, we can see that the surroundings are covered with forests and the time of receiving direct sunlight are limited. YAG is the most difficult environment to receive sunshine among the six areas. In this simulation, the power generation amount was derived by the solar locus in Fig.5. Specifically, we use the time ratio only during the sunshine time, and derived the remaining battery considering charge and consumption electricity.

Fig.6 shows a simulation results of the remaining amount of the battery. The above graph shows previous 7W system, and below graph shows new 5W system. The dotted line portion shows the period during which each system actually operated in YAG. The time of system-down correspond to the availability of the system in Fig.4. As shown in the inside of the dotted frame in Fig. 6, it can be seen that the system-down occurs frequently in the rainy season and winter season similarly to the consideration of Fig.4 shown in Chapter 4. In this simulation, it was able to obtain intermittent system-down results similar to those in Fig.4. After replacing the system in November 2016, we can confirm that the 5 W (below) is running without system-down as in the simulation even in the section expected to be shutdown in the 7 W (above) simulation.

We expect that stable operation will be realized in the rainy season and winter season after June 2017, like the below simulation results in 2016, where the system were stably running even if the weather condition were relatively severe.

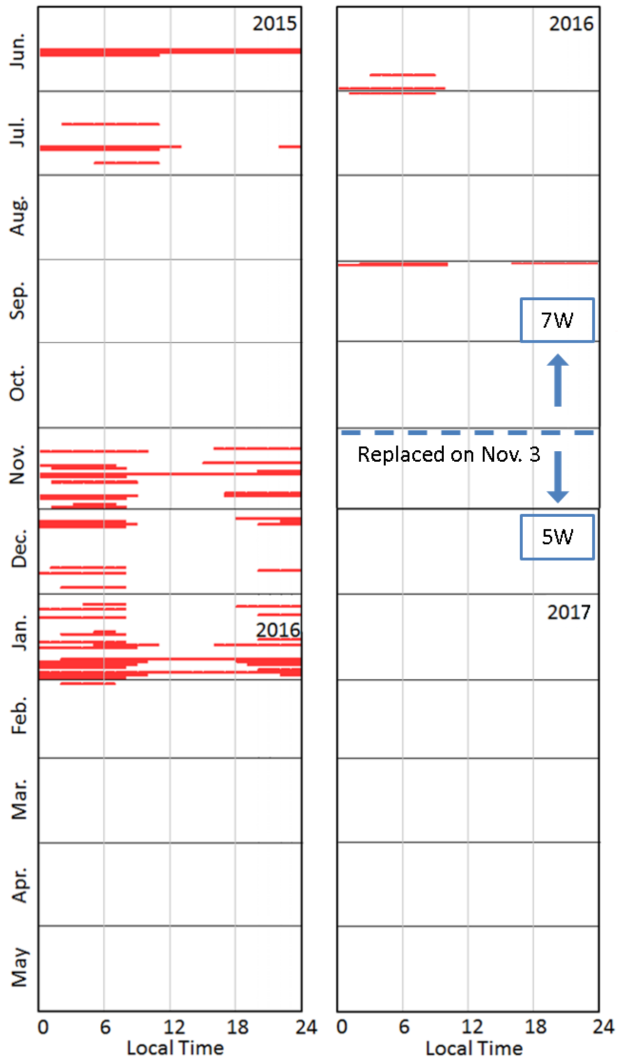

Fig.4. System availability for two years

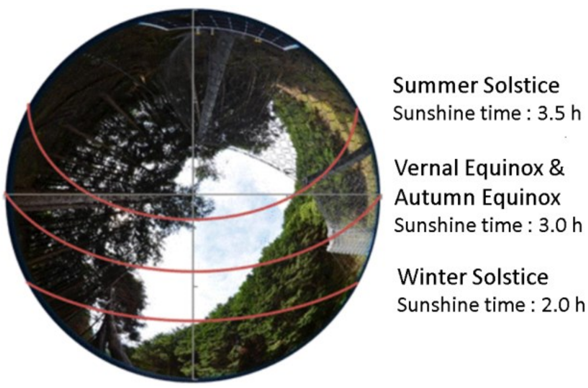

Fig.5. Solar locus and sunshine time

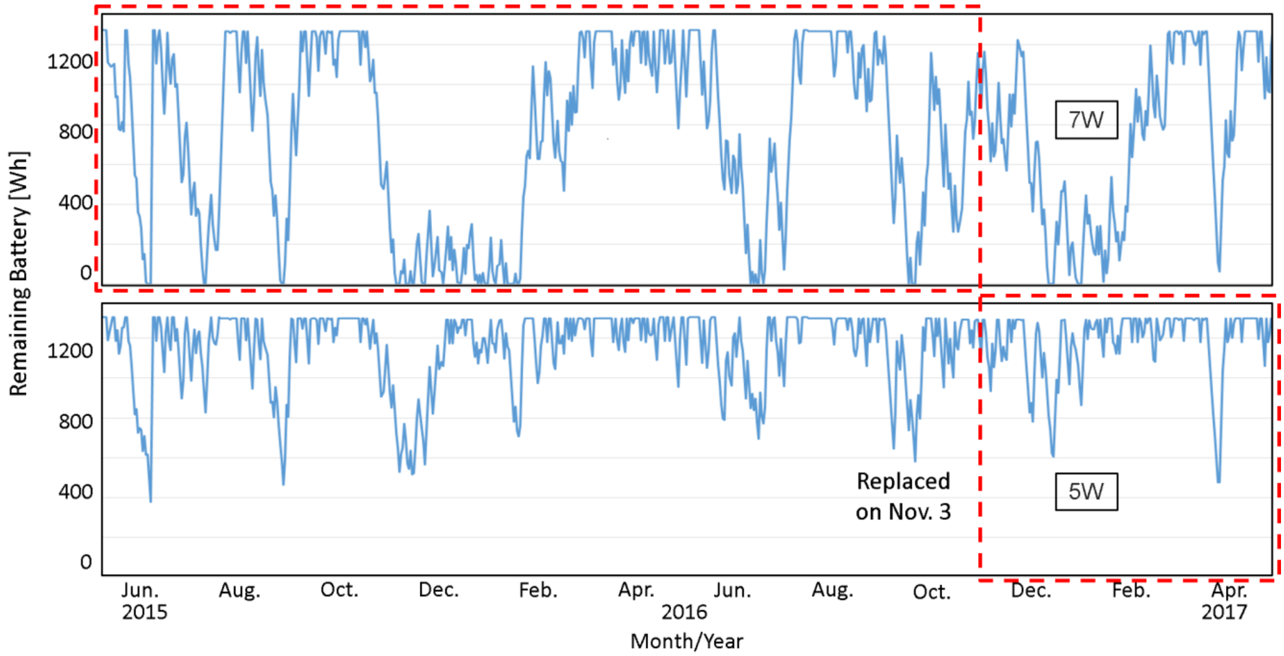

Fig6. Remaining battery simulation of 7W (above) and 5W (below) system for two years

6. Conclusion

In order to provide an environment where residents can obtain the information for evacuation judgment, we built a self-powered monitoring system for landslide disasters that can operate continuously for 24 hours.

In this study, we modeled the availability based on the operational experience, and examined the requirement to achieve stable operation. As a result, we clarified that 100% availability can be achieved by installing the power consumption of the system to 5W or less [7]. In addition, we operated 5W systems that satisfy the requirement, and accumulated operational data at YAG from November 2016 until May 2017.

In the conventional 7W system, system-down frequently occurred during the rainy season and winter with little sunshine duration. However on the 5W system, it was confirmed that system-down did not occur in winter. Therefore, by modeling the system, it became possible to more accurately check the operating status.

We evaluated the comparison between the conventional 7W system and the current 5W system by the simulation. From the results, the 5W system was able to achieve 100% availability as of May 2017.

In order to keep the non-system-down running steadily throughout the year, we will continue to accumulate our operational data and contribute to the stable operation of the system.

In the current system, it is necessary to keep watching at images, we aim not only to present images of dangerous places but also to apply the machine learning system, and the system automatically judges the degree of danger from images and notify the residents, in the future.

Acknowledgments

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