

Development of a Solar Cell Powered Slope Monitoring System

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ABSTRACT: It has been known that, the amount of rainfall in 24 hours exceeded 20% of the annual average rainfall could lead to natural disasters. In Korea, over half of the annual average rainfall is concentrated in the months of July, August and September. Consequently, natural disasters such as land slides and slope failures occur during these months. Land slides and slope failures have resulted in 318 deaths during the last ten years. This accounts for 24.4% of the total 1,314 deaths resulting from natural disasters. However, Korea's policies against slope failures center on post-disaster actions and restoration.

To prevent such damage from slope failures, it is need to install various detection sensors in areas prone to slope failure. However, in the case of the wired slope monitoring systems that are currently being utilized at some slope sites in Korea, maintenance of the systems is not easy if either the slope is too steep or is in danger of collapsing. In addition, since the slope sites are scattered all over the mountainous regions in Korea, the cost of installing power line for the system is high if the site is not nearby main power line. If the previous wired slope monitoring systems are integrated with high-tech USN technology, then limitations and problems of the previous systems can be dealt with and be addressed.

The objective of this paper is to design and implement a real-time slope monitoring system using USN (Ubiquitous Sensor Network) technology and solar cell.

Keywords: slope monitoring, slope failure, solar cell, Wireless Sensor Network (WSN), Ubiquitous Sensor Network (USN), energy

1. INTRODUCTION

70% of South Korea's terrain is mountainous regions. In addition, typhoons and concentrated rainfall occur every year in the months between July and September. Meanwhile, it has been known that the amount of rainfall in 24 hours exceed 20%

of the annual average rainfall could lead to natural disasters. Slope failures, landslides, breakdowns of retaining walls, and other such land disasters occur extensively during these months and have resulted in 318 deaths during the last ten years. This accounts for 24.4% of the total 1,314 deaths resulting from natural disasters [1]. In order

to prevent slope failures, various detection sensors should be installed in slope site which is possible to move and a detection system that can observe scientific data in real time should be set up. Then, based on the data collected by such a system, policies and measures should be established that could lessen the damage caused by slope failures. [2]

However, wired slope monitoring systems which are currently being utilized at a few slope sites in Korea, has some limitation such as maintenance of the systems is not easy if either the slope is too steep or is in danger of collapsing. In addition, due to falling stones or wildlife, power lines and communication lines are frequently severed. This leads to either partial or total dysfunction of the system. Besides, since the slope sites are scattered all over the mountainous regions in Korea, the cost of installing power line for the system is high if the site is not nearby main power line.

The objective of this study is to develop and implement a solar cell powered slope monitoring system.

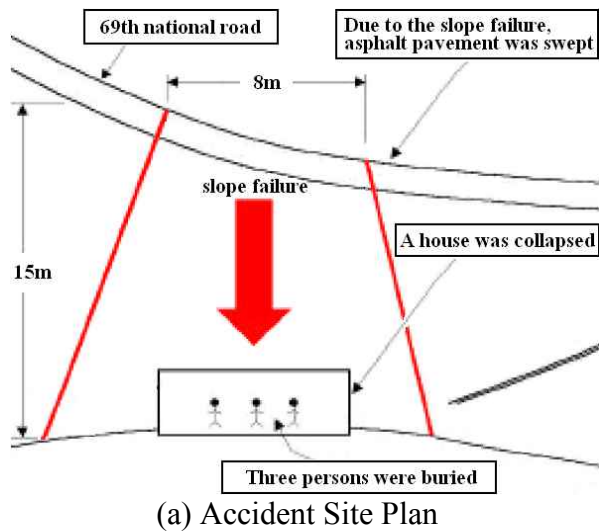
2. TRENDS OF RELATED TECHNOLOGY

2.1 Case Study of Slope Failure

On August 10, 2002, at the 69th national road in youngpo-li, wondong-myeon, yangsan-si, kyungsangnam-do, a slope of 8 meters in width and approximately 15 meters in height collapsed. The slope buried a house and 3 persons who lived in the house. The collapse seems to be of a sliding type. Because of the concentrated rainfall, the pore water pressure had gone up, and it led to the slope failure. (Refer to <Fig. 1>). [3]

2.2 Wired Slope Monitoring System

An aggressive countermeasure against slope collapse is to accurately know of slopes that are vulnerable to collapse and to protect and mitigate so that slope collapse



(b) Swept Road (c) Collapsed House
Figure 1: Slope failure site reported in Youngpo-Li [3]

does not occur. In order to predict such slope collapses, it is important to observe the movements on the surface of the slopes and research the factors that cause such movements. <Fig. 2> shows the measurement categories and measurement instruments used so far to measure slopes [4].

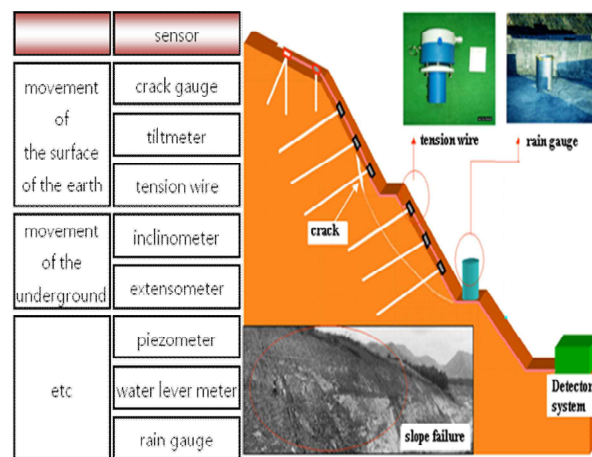


Figure 2: Type of Slope Monitoring Systems [3]

3. DEVISING OF THE SLOPE MONITORING SCENARIO

3.1 Limitations of Wired Systems

During the installation of the wired system, installation works of communication and power lines are done right at the slope. However, since the slope monitoring systems are installed in places where the potential possibility of collapse or movement is, most of the slopes for installation are steep and it is not easy to secure the working area for installation. Therefore, the danger of accident at the installation site is high and work efficiency has declined much. Also, although it is different depending on working conditions, in some installation sites, the distance between the site and main power line is too far thus greatly increasing the installation cost of the power lines.

After the installation of the system, the following are the problems that occur in the wired systems during the monitoring process. First of all, there are cases that either the communication or power lines are cut due to falling stones or wild animals. In these cases, the sensors located around the cut area do not function at all, or even if they do function, they do not relay information. Second, roadside slopes of Korea are usually located in mountainous regions. Therefore, if a lightning falls near one sensor on site, then a high voltage current flows through the installed communication or power line and in these cases, this shuts down the entire system. Third, the installation sites of the monitoring systems are scattered all throughout Korea. Therefore, neither restoration nor maintenance of the network systems is easy. Fourth, since the system use electric power, it is necessary to pay the electric charge and expense the maintenance cost for the power line. [5]

3.2 Devising of the Scenario

In order to make the wireless slope monitoring system, four modules are needed.

First, sensor module which detect object's status data, second, wireless communication module which make possible to communicate other node, third, an interface module which convert the analogue signal from the sensor to a digital signal for the communication module, fourth, Power generation and/or charging module which supply electricity to the system in isolation. The system will be installed at the slope site and be in danger of exposure to rain, fog, and air. Therefore, a waterproof and damp-proof packaging is required. (Refer to <Fig. 3>)

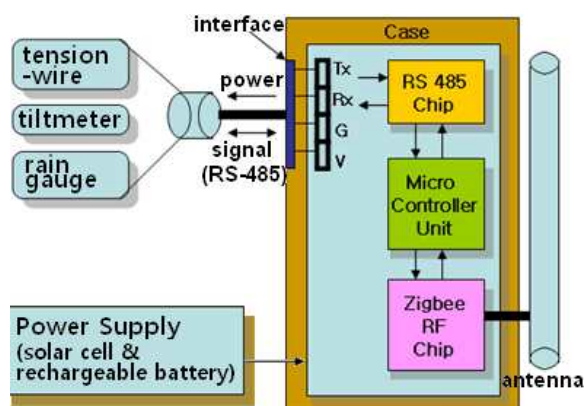


Figure 3: System Configuration

The sensors should be installed at slope sites in danger of collapse or where some possibility of movement is exist. If movements such as translation, rotation, or settlement occur at the slope surface, the tension wire and the tiltmeter should detect such movements. The movement data detected by the sensors is collected into a data log via ZigBee wireless communication network. The collected data is then sent to a server system which is in the control center through CDMA network. The schematized flow is shown in <Fig. 4>.

4. DEVELOPMENT AND TEST OF THE SYSTEM

4.1 Development of Sensor Node

Since there are wired slope monitoring systems pre-existed, the prototype system is

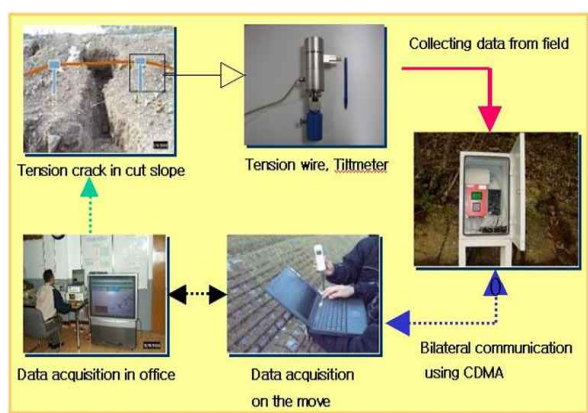


Figure 4: Flow Chart of Slope Collapse Monitoring

developed applying USN technology and solar cell to a pre-existed system. The system developed in this study used a tension wire for the measurement of surface change, two tiltmeters to measure the slant along both the X and the Y axis. In addition, a rain gauge was used for precipitation measurement. In the case of the tension wire and the two tiltmeters, a TRS (Translation, Rotation and Settlement) sensor that combines all the sensors into one product was used. In this study, wireless communication module and interface module are combined with TRS sensor as one product. For supplying power, solar cell and battery are used as shown in <Fig. 5>

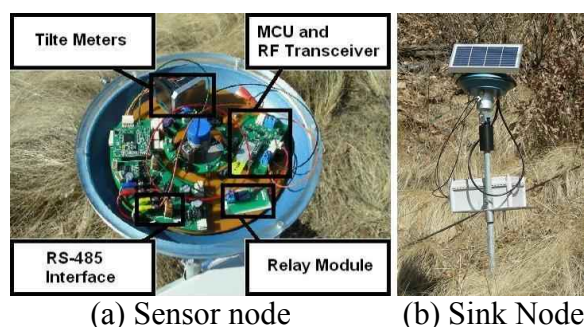


Figure 5: Sensor node and solar cell

4.2 Installation of the System

In this study, to analyze the performance of the developed system, we set up and test the system at an actual slope site. The primary objectives of the test are the

following: to confirm the reliableness of wireless communication between the sensor nodes and the sink nodes, to test data transmission using CDMA, and to verify the adaptability of the system at actual slope environments.

The installation site shown in <Fig. 6> is a slope site in Kumho national Institute of Technology (KIT). The site was selected as a test installation site for the prototype system. Therefore, we chose a slope that was relatively secure and less steep in the slope angle among the many slope sites that had wired monitoring systems installed on it. For the prototype system, 8 TTW sensors, 1 rain gauge, 9 sensor nodes, 2 sink nodes, and 1 gateway (including a CDMA modem) were used. The system in control center was consisted of a PC and a laptop PC with an application and CDMA modem installed on it.



Figure 6: System Installation Site

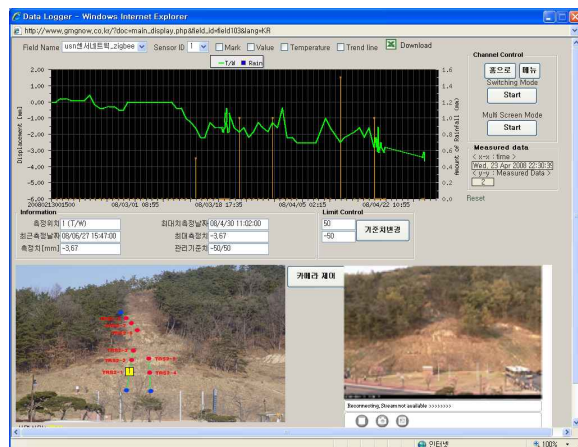
4.3 Test of the System

The following are the results after having operated the prototype system at the testbed site.

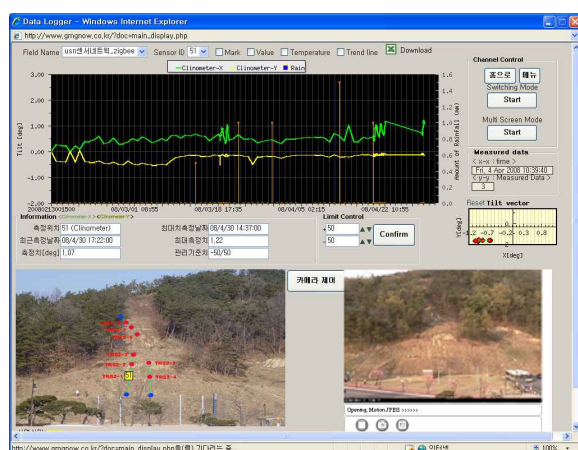
First, we confirmed that there were no major problems in operating the system powered by solar cell.

Second, looking at the results from the testing of wireless communication between

nodes on the site, we could note partial problems in data transmission between the sensor nodes and the sink nodes in the initial model. Some data were omitted or wrong values were transmitted. The cause was that the sensor nodes went back and forth between sleep mode and wake mode to lessen power consumption. However the pre-existing TRS sensors had not been developed with these mode switches in mind. Therefore, we were able to confirm that is where the errors occurred in data detection and transmission. After the problems were addressed and fixed, it can be seen in <Fig. 7> that data collection at the same level of wired systems is being done.



(a) Data Collected by Tension-wire No.1



(b) Data Collected by Tiltmeter No.51 & 52

Figure 5: The Result of Data Collection

5. CONCLUSION

The objective of this study is to develop and implement a solar cell powered slope monitoring system and to verify the validity and adaptability of such a system through onsite tests. To achieve the objectives, the present study did the following: First, a case of slope failure and the conditions of previous slope measurements were investigated and analyzed. Second, a scenario was devised for the selected sensor concerning sensor modules, sensor nodes, sink nodes, gateway, and application. Based on the scenario, a system was designed and developed and then a prototype system was set up. Third, the system was installed at testbed site in KIT and tested onsite for adaptability.

As a result of the onsite testing, we confirmed that it is possible for operating a sensor network to use a solar cell. In addition we found and correct some minor problems in wireless communication and thus far there have not been any significant problems in operating the system.

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