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SLOPE MONITORING SYSTEM FOR NUCLEAR POWER PLANTS

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ABSTRACT

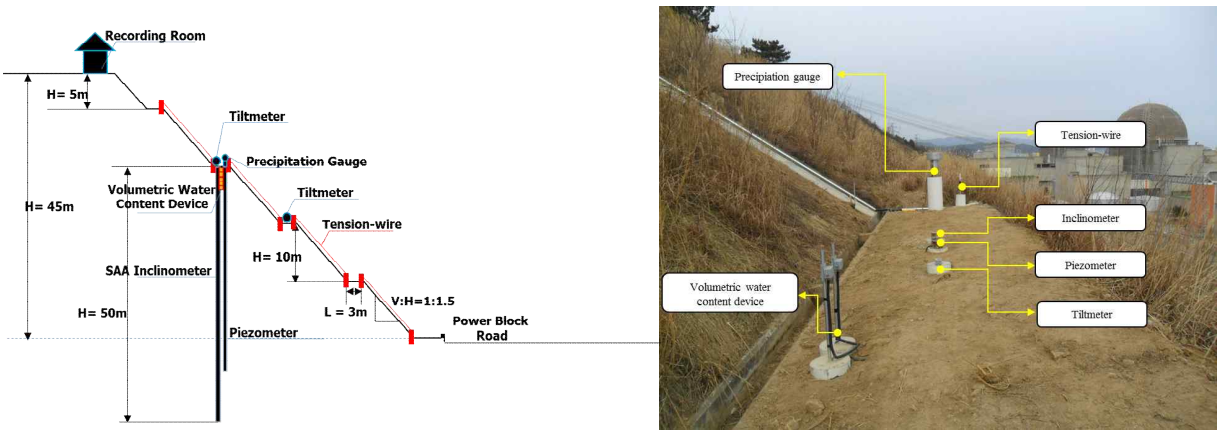
When the great earthquake of east Japan had been occurred in 2011, embankment slope failure at the NPP site caused a station blackout, which led to loss of cooling function and ultimately resulted in release of radioactive materials to the outside environment (Massaki et al., 2014). Besides the seismic loading, rainfall has an effect on the slope stability. Generally the most important factors among the external loadings are earthquake and rainfall. But according to the increasing localized heavy rainfall in Korea, a lot of slope failures have been occurred. Subsequently, the importance of the slope safety in NPP sites drew attention from the nuclear power industry. KHNP (Korea Hydro & Nuclear Power Co., Ltd.) regularly has been carrying out inspection on the slopes at NPP sites. Because most of the inspections had been performed by naked eye, inspectors cannot figure out small or invisible deformation. So KHNP developed K-SLOPE System (KHNP SLOPE Maintenance & Management System) to establish much more systematic and quantitative measurement of slope behaviour by installing several kinds of monitoring devices.

INTRODUCTION

Typically, monitoring means not only simple measuring but also understanding of overall state by installing monitoring devices. Through the slope monitoring, inspectors could figure out precise slope behaviour. KINS(2011), US NRC(2007) and IAEA(2011) guidelines recommend slope monitoring during and after construction to detect occurrences that could detrimentally affect the NPP facilities. KHNP had reviewed several kinds of monitoring devices like piezometer, global positioning system, settlement monument, photogrammetry, inclinometer, tiltmeter, seismometer etc., monitoring methods and installation location. Finally selected monitoring devices were inclinometer, tiltmeter, piezometer, tension-wire, precipitation gauge and volumetric water content device. Installed slope location is behind of OO NPP reactor building in Korea and its slope height is 45m. Measuring by each monitoring devices is automatically performed in every 1 hour and recorded by the data logger installed at site. Measured data are transmitted to analysis server in KHNP Central Research Institute and automatically analysed by management criteria established by KHNP.

SELECTION & INSTALLTION OF SLOPE MONITORING DEVICES

Figure 1 is slope monitoring devices installed in OO NPP site. Total 6 different types of monitoring devices had been installed as shown in Figure 1. Piezometer 1 set, tiltmeter 2 set, volumetric water content device(V.W.C) 5 set, tension wire 4 set, precipitation gauge 1 set, inclinometer 1 set were installed in or on the slope. Monitoring devices are shown in Figure 2 and a representative installation procedure for inclinometer is displayed in Figure 3.



(a) Monitoring device arrangement (b) Installed slope monitoring devices

Figure 1. Slope monitoring devices installed in OONPP site

(a) Inclinometer (b) Tiltmeter (c) Piezometer (d) Tension wire (e) Precipitation Gauge. (f) V.W.C device

Figure 2. Monitoring devices installed in OO NPP site

(a)Opening access road (b)Boringmachine movement (c) Boring (d) Protection tube installation (e) Spacer Installation (f) Inclinometer Insertion

Figure 3. A representative procedure of inclinometer installation

The purpose of each monitoring device is shown in Table 1.

Table 1. Purpose of monitoring device installation

Type of Device	Location	Purpose
Inclinometer	Bore hole	Deformation of slope
Tiltmeter	Ground surface	Change of slope surface angle
Piezometer	Bore hole	Monitoring of ground water table
Tension Wire	Ground surface	Deformation of slope
Precipitation Gauge	Ground surface	Measurement of precipitation
Volumetric Water Content Device	Subsurface	Change of volumetric water content

DATA TRANSMISSION & ANALYSIS

Measured data are temporally stored at field data logger installed in monitoring recording room in every 1 hour and automatically transmitted to analysis server installed KHNP Central Research Institute by TCP/IP communication. K-SLOPE System arrangement is shown in Figure 4. Analysis server automatically run analysis program and perform all kinds of data analysis by KHNP's management criteria in every 1 hour. And its result is displayed in user's screen (Figure 5).

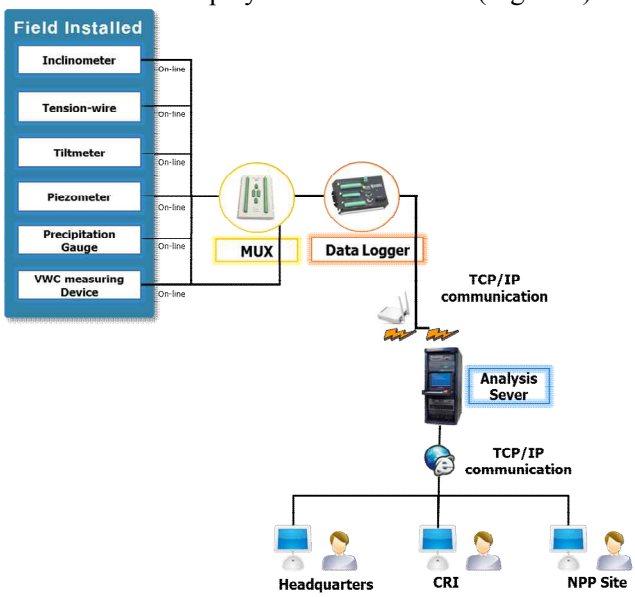
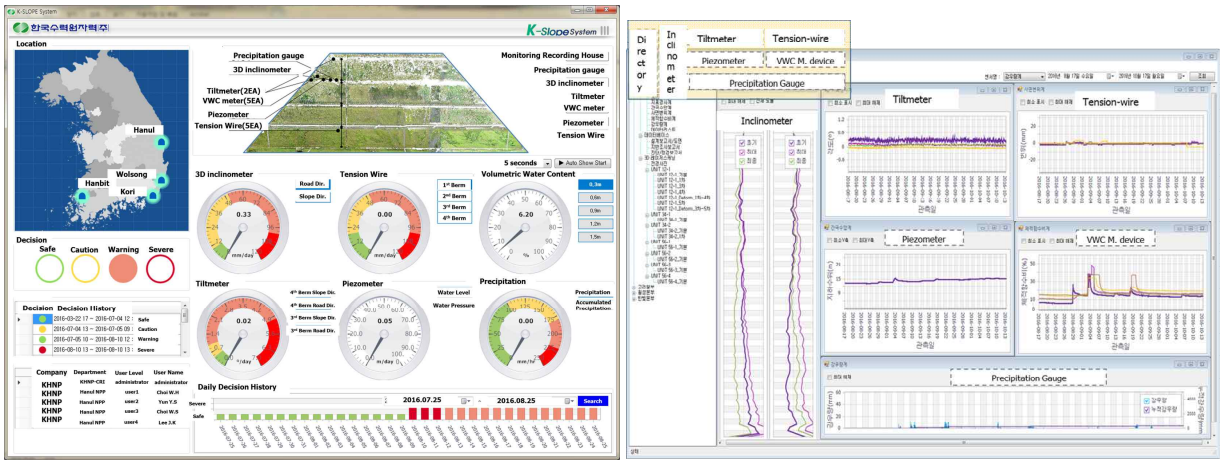


Figure 4. K-SLOPE System Arrangement



(a) Monitoring screen (b) Graph screen

Figure 5. K-SLOPE System

K-SLOPE System is composed of monitoring and graph screen. In the monitoring screen, monitoring location, decision for slope stability, decision history, users, monitoring device installation location in the slope, current value for each monitoring device and daily decision history are displayed. Decision represents the current state of the monitoring slope stability. It is divided into safe, cautious, warning and severe stage. Management criteria established by KHNP is shown in Table 2 and also KHNP criteria consider daily displacement, cumulative displacement, precipitation per hour and precipitation per day at the same time. Among the monitoring values most conservative value is adopted in the K-SLOPE System.

Table 2. Management criteria for slope stability

Type of device	Unit	Decision for slope stability				Remarks
		Safe Stage	Cautious Stage	Warning Stage	Severe Stage	
Inclinometer	mm/day	~10	10~50	50~100	100~	daily displacement
Tiltmeter	°/day	~0.5	0.5~1.0	1.0~5.0	5.0~	daily angle change
Tension wire	mm/day	~10	10~30	30~50	50~	daily displacement
	mm/all	~20	20~50	50~100	100~	cumulative displacement
Precipitation	mm/hr	~30	30~40	40~50	50~	hourly precipitation
	mm/day	~100	100~180	180~220	220~	daily precipitation
Volumetric Water Content	%/day	~20	20~25	25~30	30~	N/A
Ground water level	m/day	~0.5	0.5~1.5	1.5~2.0	2.0~	N/A

CONCLUSIONS

Up to recently slope management and maintenance in NPP sites are mainly performed by naked eye inspections. To understand slope behaviour in detail, it is generally needed to develop slope monitoring system. Slope monitoring system enables more systematic and quantitative slope maintenance and management. And also invisible deformation could be detected by monitoring devices.
KHNP constructed K-SLOPE system successfully. 6 kinds of monitoring devices were installed in OO NPP site. Every 1 hour measured data are automatically recorded and transmitted to analysis server. Automatic analysis is performed by analysis server according to the slope maintenance criteria established by KHNP and its analyses results for current slope stability are displayed in user friendly screen.

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