Online Web Based Monitoring of Landslides using Geotechnical Instrumentation and Automatic Surveying Techniques

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Abstract

For control and mitigation of disastrous consequences caused by landslides, it is essential not only to take preemptive corrective action at the site by strengthening the potentially unstable slopes but also to implement a good prediction and forewarning system. The latter is vital for identification of hazardous conditions or developments well before a catastrophic failure takes place and alert personnel with authority to take remedial measures as early as possible. This paper describes the advanced landslide monitoring network developed by the author's organization comprising of field-proven and rugged geotechnical instruments, advanced automatic surveying techniques and public cloud-based web data management system. The field sensors for measuring parameters such as subsurface deformations, porewater pressure, anchor load, rainfall, surface crack movements etc. are connected to the field datalogger through a SDI-12 bus, thus minimizing the cabling costs and increasing system's reliability. Deployment of the robotic total station to automatically monitor 3D prisms at critical locations adds to the comprehensiveness of the data collected and system's integrity. The data collected by the field instruments and sensors, transmitted using GSM/GPRS network, is readily available in real time to the different stakeholders, who may be located in any part of the world. Automatic notification of alarm conditions through e-mail or SMS is realized by the system. The network is cost-effective and value-wise is just a small fraction of what is spent later on in rescue operations, removing debris and rehabilitation.

Keywords: *Landslides Instrumentation & Monitoring, Web-based data monitoring service, RF sensor network*

1. Introduction

Landslides are one of the major natural hazards causing loss of life and damage to infrastructure worldwide. Needless to say, the economic consequences of landslides are grave. Instrumentation plays an important role in understanding the behaviour of a slope and gives early signs of an impending failure. This enables instituting an early action to contain or minimize the losses. With advancements in technology, instrumentation and monitoring systems are becoming more and more effective both functionally and cost wise. It is possible to have the access to data in near real-time from any part of the world on a wide array of devices. The alarm generated automatically by the system upon breach of any trigger value is one of its crucial functions.

2. Components of a landslide monitoring network

It is necessary to have a combination of instruments across different sensing technologies to give complete information about a potential landslide area. Ease of installation and communication setup is equally important, apart from proven sensor types and core-technologies to achieve an effective and long-term landslide monitoring system. Various building blocks of the system are described in the following paragraphs:

2.1.Field instruments

Essential field instruments for landslide monitoring are shown in figure 1 below with the description given in table 1:

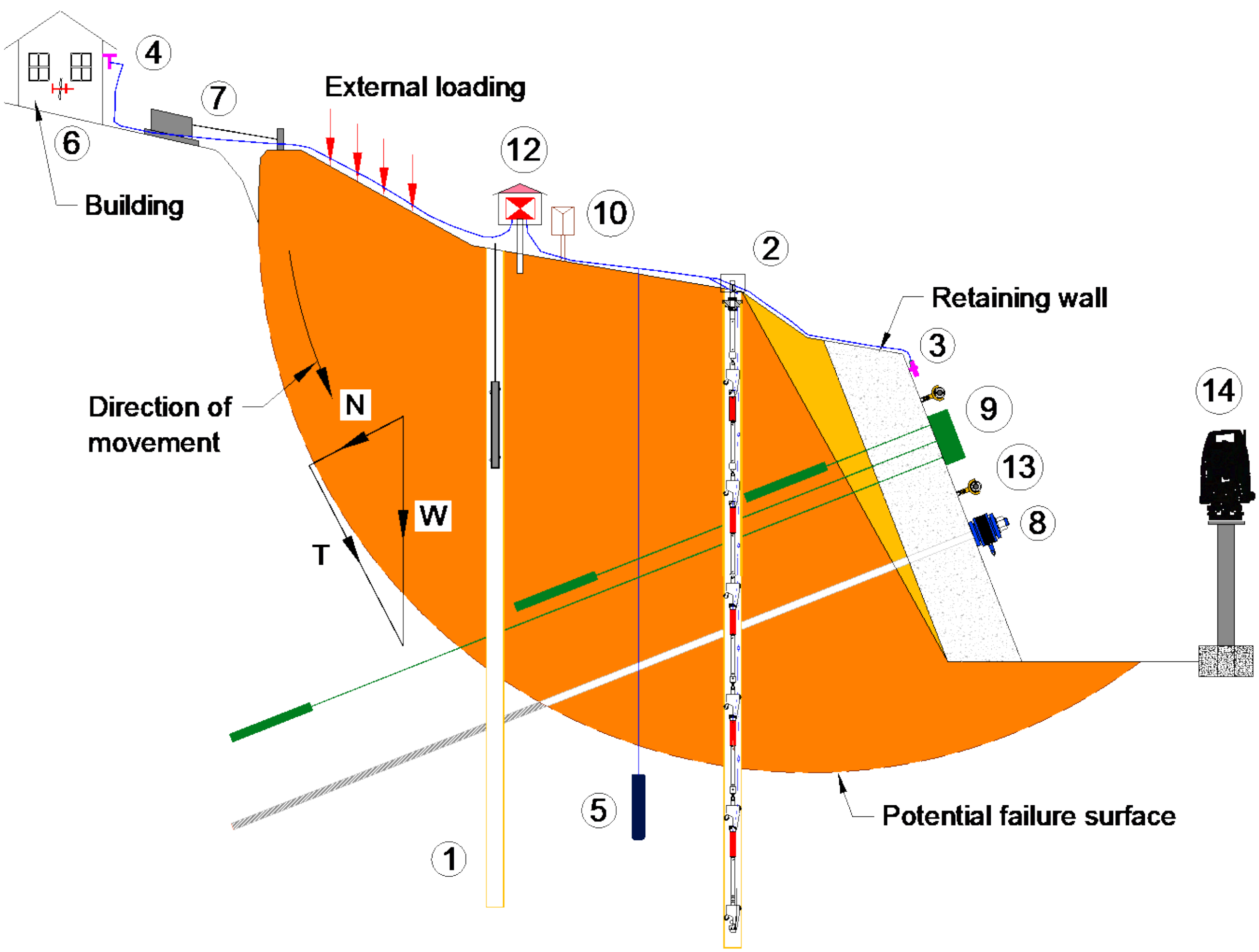

Figure 1: Field instrumentation for landslide monitoring

Table 1: Instruments suitable for monitoring slope stability

Sl. no.	Name of instrument	Type surface or subsurface	Reading method	Parameter monitored
1.	Inclinometer	Subsurface	Manual	Shear zones and lateral movements
2.	In-place Inclinometer	Subsurface	Automatic	Shear zones and lateral movements automatically at desired intervals which could be as small as once every few minutes
3.	Fixed tiltmeter	Surface	Manual or Automatic	To monitor change of tilt on retaining walls, rocks and buildings/structures, that may displace
4.	Tilt-logger	Surface	Automatic	To monitor change of tilt on retaining walls, rocks and buildings/structures, that may displace; A combination of tiltmeter and SDI-12 datalogger with GSM/GPRS modem
5.	Piezometer	Subsurface	Manual or Automatic	To monitor pore water pressure vibrating wire or hydraulic (Casagrande) piezometer. Latter is monitored manually using a dip meter probe or water level sounder, while VW piezometer can be automated

6.	Crack meter	Surface	Manual or Automatic	Displacements/openings in cracks
7.	Creep meter	Surface	Manual or Automatic	Displacements of potential landslide zone
8.	Center hole load cell	Surface	Manual or Automatic	Monitoring of load in ground anchor
9.	Multi-point borehole extensometer	Subsurface	Manual or Automatic	Movement inside slope at various depths
10.	Rain gage	Surface	Manual or Automatic	Rain fall-tripping bucket rain gage
11.	Readout logger (not shown in figure 1)	NA	Manual	For measuring vibrating wire or strain gage based sensors with data storage capacity with date and time of taking readings
12.	SDI-12 datalogger	NA	Automatic	Automatic datalogger for monitoring all types of SDI-12 electronic sensors. Features an in-built GSM/GPRS modem
13.	Prism target	Surface	Manual or Automatic	Acts as a target for ATS and installed on retaining wall or at land/rock mass
14.	Automatic Total Station (ATS)	Surface	Automatic	For automatically reading x, y & z coordinates of the prism targets with control box with GSM/GPRS modem

15.	RF dataloggers (not shown in figure 1)	NA	Automatic	Automatic datalogger for monitoring all types of electronic sensors. Features RF data transmission
16.	RF gateways (not shown in figure 1)	NA	Automatic	Communicates with RF dataloggers and collects data. Transmits the data collected using GSM/GPRS network

2.2. Automatic 3D deformation monitoring system (ATDMS)

The ATDMS system measures movements of targets fixed at critical locations on retaining wall of a slope or slope itself, in three dimensions (x, y & z). It comprises of the following major components:

- 3D prism targets
- Automatic total stations (ATS)
- Control box
- Monitoring database

3D prism targets (figure 2) are installed on the face of the retaining wall of the slope or on the slope itself in a grid form or at critical locations.

Figure 2: Prism target

One or more high precision servo driven, computer controlled ATS is installed at a suitable location on concrete/steel pillars with protective enclosures to automatically sight these points sequentially and record data. Reference prism targets at stable locations make the system complete. Refer to figure 3 for possible mounting arrangements of the ATS.

The ATS is controlled by a control box (figure 4) which is essentially rugged field computer. 220 V, 50 Hz AC power supply is required for the control boxes which in turn power up the ATS. Solar panels can be used where mains power supply is not available. Control box features GSM/GPRS modem with dual SIM slots for data transmission. Data is collected by the public cloud-based web data monitoring service described in section 3. Alarms can also be programmed in the database resulting in sending SMS/e-mail alerts automatically to the concerned personnel, in case any trigger value is breached.

Figure 3: ATS with different mounting arrangements

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Figure 4: ATS control box

2.3 Communication & data transmission

2.3.1 SDI-12 bus communication The SDI-12 system is a bus communication system in which several sensors can be connected to a single 3-core cable, as the electrical interface for the protocol involves three lines: a serial data line, a 12 V power line, and a ground line. It is a great advantage of the system that a wide array of landslide monitoring sensors can be interconnected in a serial bus to an SD-12 datalogger using a single 3 conductor cable. The datalogger, featuring GSM/GPRS modem transmits the logged data over the internet to the web-based data monitoring service described later. Refer to Figure 5 for a block diagram of slope stability sensors network built on a SDI-12 bus.

Figure 5: Slope stability sensors on a SDI-12 network

2.2.2 RF communication

Landslide monitoring sensors network with radio frequency (RF) communication does not require any cabling. It essentially comprises of sensors connected to RF dataloggers and gateways (figure-6) and features long-range communication on an ISM frequency range of 865-867 MHz of up to 15 km in open field conditions (figure-7). The low power consumption of the system results in datalogger batteries lasting up to 5 years.

The RF dataloggers, often called the 'nodes' of the wireless network, can be easily configured in the field using the smartphone Android app provided. These are available in single and multichannel configurations suitable for receiving vibrating wire and analogue inputs and automatically collect, store and transmit data from the connected sensors. The RF gateway controls the network and is the aggregator of all data collected by the nodes. It has an integrated 3G modem with antenna supporting HSDPA, EDGE & GPRS, and a high sensitivity GPS-GNSS module. The gateways transmit the data over the internet to web data monitoring service.

The system offer benefits by means of hassle-free installation, as cable runs-often long and tedious at the landslide monitoring sites-are not involved, cost & time savings, remote monitoring of hard to access locations, easy expansion of the system if required in future, and easy maintenance.

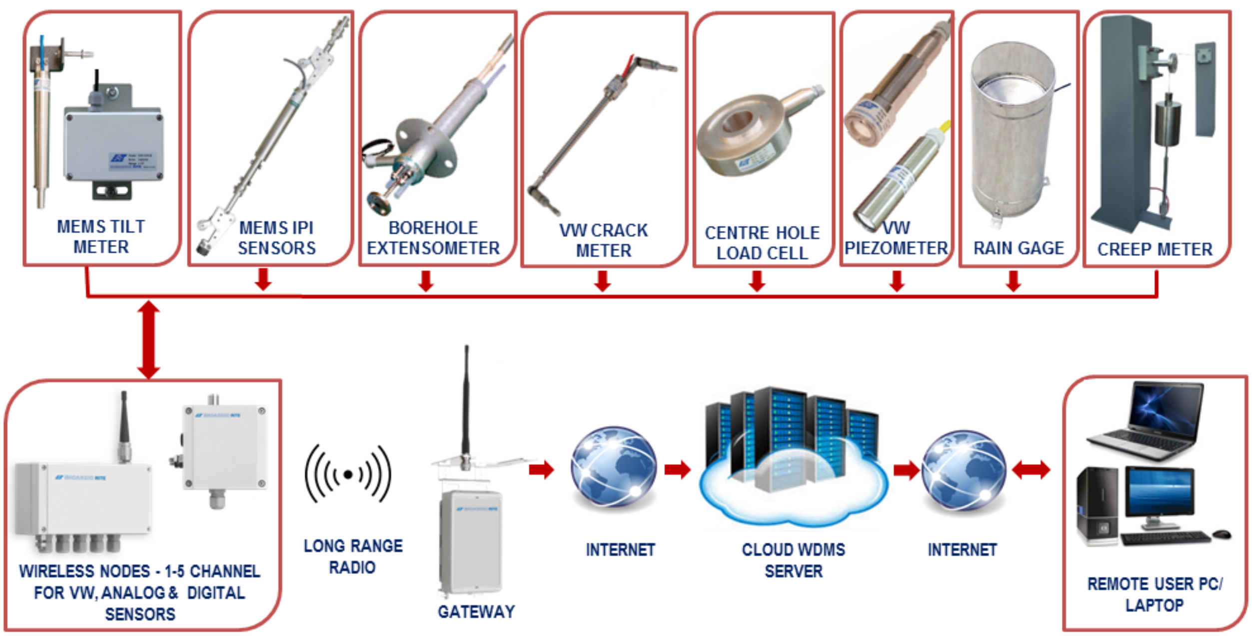

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Figure 6: Slope stability sensors RF network using RF dataloggers and gateways

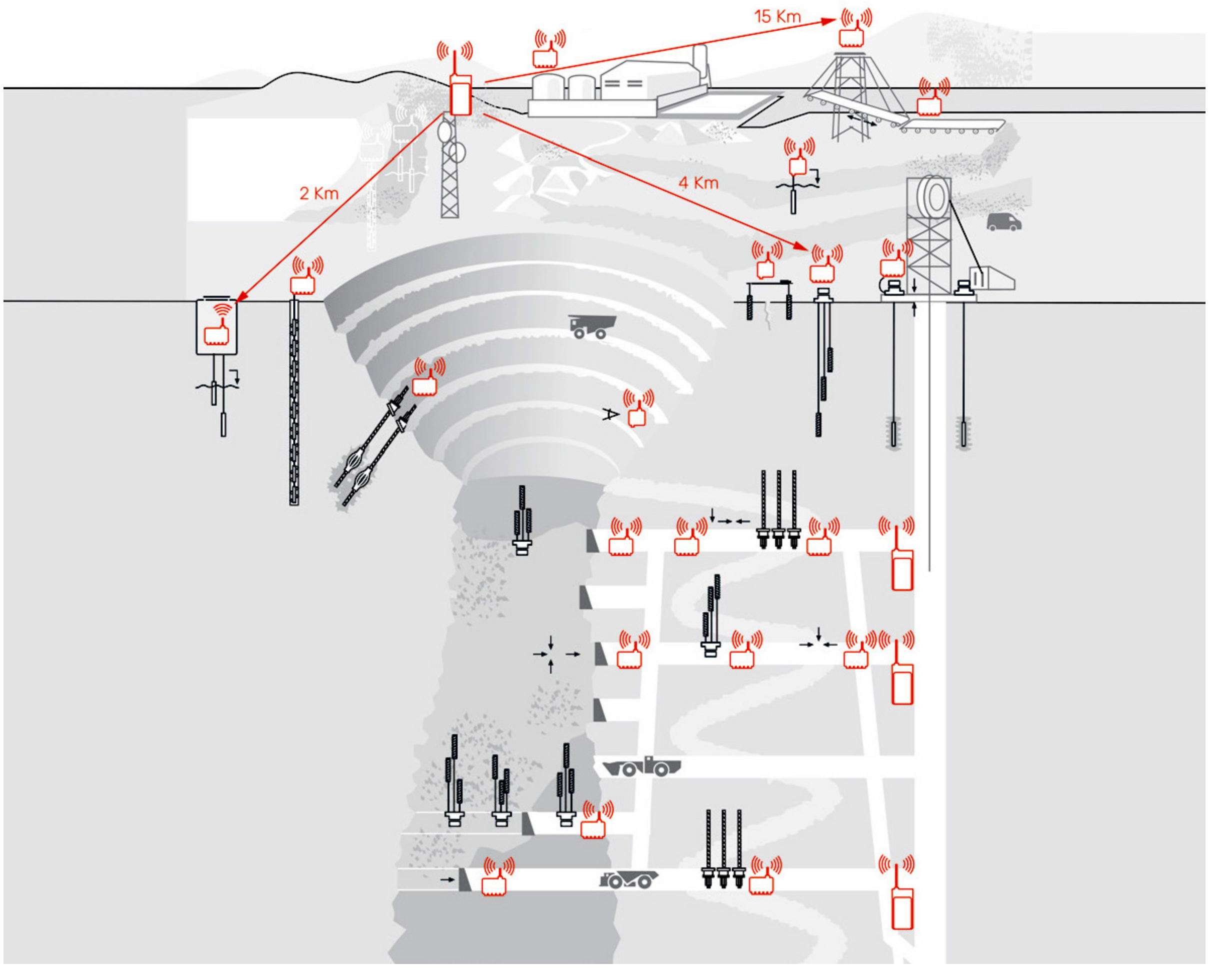

Figure 7: Typical RF sensor network at field

Figure 8: RF gateway

3. Web-based data presentation and alarms

Public cloud-based web data monitoring service (WDMS) is available for online data access in near real time. The WDMS retrieves data from the SDI-12 or RF dataloggers and ATS control boxes, archives the retrieved data in a SQL database, processes data and presents it in tabular and most suitable graphical forms (figure 9) for easy interpretation. This is a highly flexible monitoring data management system that can combine data from geotechnical, structural, geodetic and environmental sensors.

Usually, the WDMS works on a rental model. The user has to pay a small setup fee for the first time and then a monthly rental has to be paid for accessing the data over the cloud as long as required.

Features of the WDMS can be summarized as follows:

- Data from multiple sensor types are converted into meaningful information in graphical as well as numerical format
- Layout plan can be incorporated with locations of each monitoring sensor. From this layout plan, the user can easily navigate to graphical & tabular data of any sensor with a few mouse clicks
- Access to all sensors in one platform
- Instant automatic alerts via SMS or e-mail to authorized personnel
- Generate settlement and piezometric contour
- Create graphs from any combination of parameters and time period
- Variety of visualization and analysis tools to identify potential failure scenarios
- No special software required for accessing the user sites as information can be viewed using most standard and popular web browsers on a wide range of fixed and mobile devices such as PCs, tablets and smartphones.

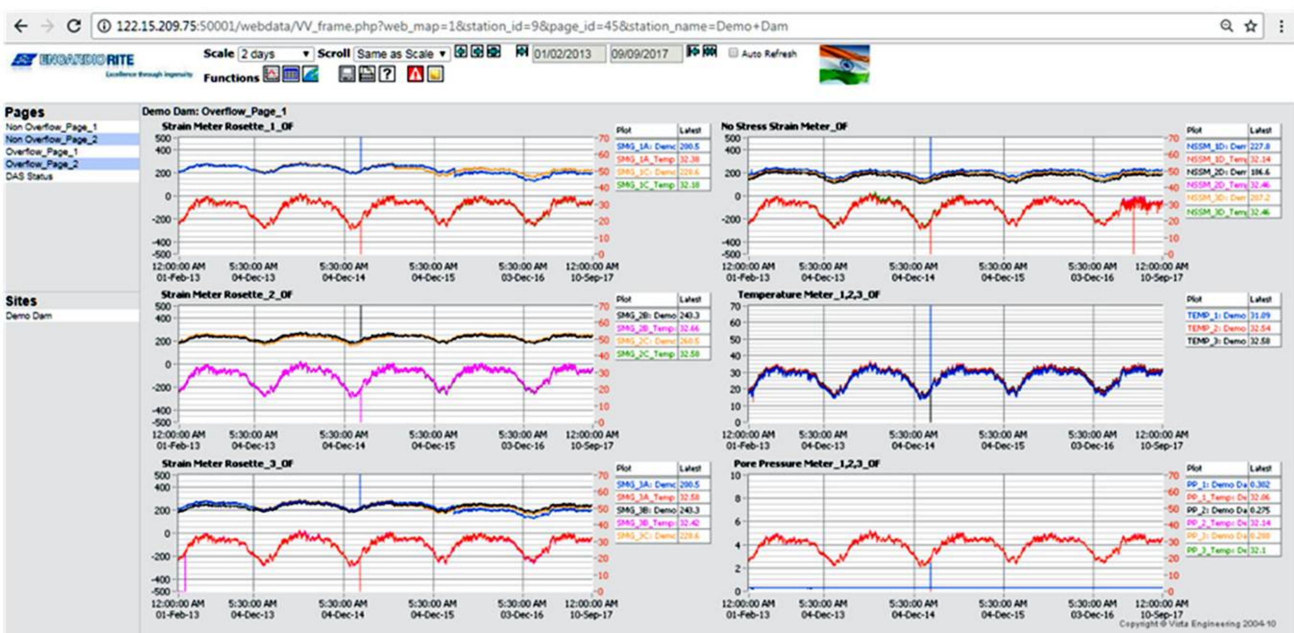

Figure 9: A screenshot of the historical data window of WDMS

4. Conclusions

By implementing proper drainage for groundwater, using anchor bolts and cable anchors at the right places, pressure grouting and building retaining walls etc., it is possible to contain the landslide to a large extent. Apart from ground investigations and remedial measures, a balanced and well-executed instrumentation system can provide data for greater understanding triggering mechanisms and deformation behaviour of a slope in great detail. By monitoring slope movement, corrective action may become possible earlier than the occurrence of the landslide. The solution for setting up a landslide instrumentation & monitoring system is not expensive with the advent of new technologies in this field. Considering holistically, the cost of instrumentation and monitoring is a small fraction of what is spent later on in rescue operations, removing debris and rehabilitation.

References

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