INTRODUCTION

A good prediction and forewarning system when implemented with effective efforts to control and mitigate landslides can drastically reduce destruction caused by landslides. Unstable slopes require monitoring systems that can be accessed remotely and provide immediate warning in case of failure. Advances in geotechnical/surveying instrumentation and data transmission systems now make it possible to monitor these slopes conveniently and economically.

Remote (near real time) monitoring of slope movement can be an effective approach for many unstable or potentially unstable slopes. Water levels can be observed using vibrating wire piezometers. Lateral movements and deformation can be determined with in-place inclinometers, tilt meters, extensometers and automatic survey systems.

All of these instruments are connected to a datalogger that collects reading at selected intervals and trigger an alarm or sends a SMS if pre-determined values are exceeded. Data can be transferred using cellular network or radio frequency technologies, depending on site conditions. Collected data can be evaluated by an engineering geologist and consultant to take corrective measures and prevent landslide problems, present or expected in future.
SOLUTIONS AVAILABLE FOR LANDSLIDE/SLOPE MONITORING

Following solutions available with Encardio-rite can be used for online web based data monitoring:

- Geotechnical sensors to measure all relevant parameters required to monitor structural behavior
- Automatic monitoring of geotechnical sensors using SDI-12 digital interface datalogger with GSM/GPRS telemetry
- Automatic monitoring of geotechnical sensors using LoRa nodes and a gateway
- Monitoring with automatic total stations with GSM/GPRS telemetry
- Public cloud based web data management service

INSTRUMENTATION

Instruments available with Encardio-rite for surface and subsurface online monitoring are as follows:

- In-place inclinometers for monitoring sub-surface lateral movements
- Piezometer for monitoring pore pressure variations throughout the landslide area
- Tilt meters mounted at one or more locations on the retaining wall/buildings in zone of influence to record changes in slope inclination
- Borehole extensometers for settlement and deformation
- Center hole load cell for monitoring tension in anchors used for stabilizing the slope
- Crack and joint meters for monitoring displacement/opening of cracks in buildings/structures
- Creep meter with invar wire for monitoring displacement/opening of faults in the ground
- Rain gage for monitoring rainfall
- Dataloggers/Data acquisition systems
- Automatic total stations
- Web data management services

SDI-12 INTERFACE REALTIME MONITORING

Encardio-rite offers advanced automatic dataloggers with GSM/GPRS for data collection of geotechnical instruments with SDI-12 digital interface and transmission to remote server. Refer to block diagram above.

The dataloggers can be programmed to take a measurement from 5 seconds to 168 hours. For better battery life, it is recommended to transfer the logged data 2-4 times/day. The measured data is stored, together with the current date, time and battery voltage, as a data record in the internal non-volatile memory of the datalogger.

The advantage of the system is that only a single 3 conductor cable is required to interconnect all the sensors and the datalogger in a serial bus. SDI-12 is a multi-drop interface that can communicate with multi-parameter sensors.

WIRELESS REAL TIME MONITORING USING RF

Encardio-rite offers state-of-the-art wireless monitoring solution comprising of wireless dataloggers compatible with a wide array of geotechnical sensors and gateways.

The radio-communication devices are battery powered and are based on LoRa technology and provide 'Long
Range’ communications on a wide area network (WAN) using very low power levels.

Data collected from the remote field sensors can be viewed in near real time by the authorized users from any part of the globe by logging on to Encardio-rite’s WDMS. Refer to block diagram given below.

The system features long communication on an ISM frequency range of up to 10 km in open field conditions.

Low power consumption of datalogger results in batteries lasting for up to 5 years.

The wireless dataloggers, functioning as nodes of the wireless network, are available in single and multichannel configurations suitable for receiving digital inputs from vibrating wire and analog devices to automatically collect, store and transmit data from the connected sensors. The gateway is the aggregator of all data collected by the nodes. It has an integrated 3G modem and transmits the data over the internet to the WDMS.

The system offer benefits such as cost & time savings, remote monitoring of hard to access locations, easy expansion of the system, if required in future and easy maintenance.

**AUTOMATIC SURVEYING SYSTEM**

Encardio-rite offers an automatic three-dimensional deformation monitoring system with highest accuracies achievable in the industry presently. Displacement data is retrievable by logging on to Encardio-rite’s WDMS. The system ensures near real time monitoring of displacement, providing high measurement density, simultaneous wireless transmission and availability of data on-line in easy to understand movement vectors in graphical and tabular formats. The system can be accessed and controlled remotely by the users.

**AERIAL SURVEY WITH DRONES/UAV**

This is a rapid and safe way of collecting data from large scale landslide areas and mountains where mm accuracy is not necessary but motion of mass is vital to be determined.

Unmanned and remotely piloted aircrafts follow a preprogrammed flight path. Equipped with HD/IR/Thermal cameras, they capture aerial images...
over a defined area. The point clouds, meshes and 3D models produced are the data to be compared between sequel flights during monitoring interval.

Web data monitoring service consists of in-house developed Drishti or Terramove data management software. Drishti is used for providing services where only geotechnical instruments are used. Terramove is used where data is collected/correlated from both geotechnical instruments and automatic total stations.

Encardio-rite cloud services work on a rental model. User has to pay a small setup fee for 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 data management software can be summarized as follows:

- Data from multiple sensor types is 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 get data in graphical form of any sensor with few mouse clicks.
- Access to all sensors in one platform
- Instant automatic alerts via SMS or email to authorized personnel
- Generate combined charts of related parameters
- 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
- Can be accessed using tablets and smartphone