Dam Safety Monitoring Solution

SOUTH Deformation monitoring team was founded in 2007, with more than 10 years development, monitoring team now have 200+ people, more than 600 project experiences.

◆Significance of Dam Monitoring system construction

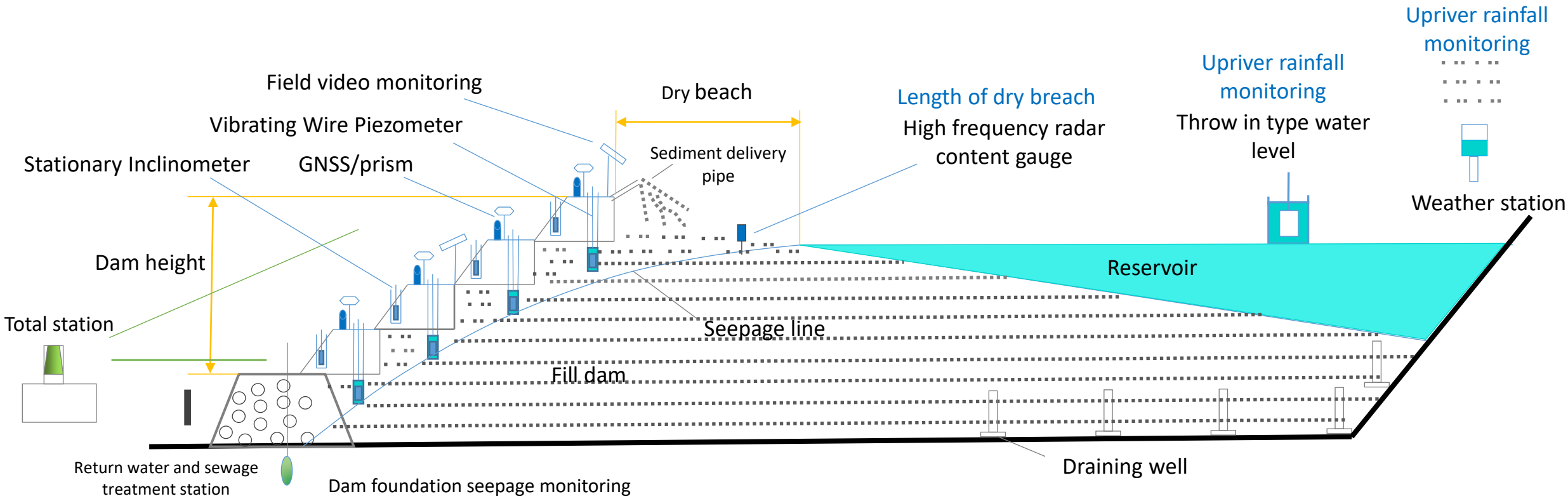
In order to optimize the allocation of water resources and ensure the safe operation of reservoir dams, it is necessary to build an automatic safety monitoring and early warning system for reservoir dam. The expected objectives of the system include: understanding the deformation behavior of the reservoir dam, the safety during the construction period and the safe operation after completion, better serving the safety production and giving full play to its economic benefits. After the system is completed, the following functions will be realized:

(1) Monitor the performance changes during dam construction and operation, timely feed back early warning and provide data when structural abnormalities occur, so as to analyze the abnormal site, guide the dam management department to take measures to prevent accidents and ensure the safe operation of the reservoir dam.

(2) The system analyzes the monitoring data at any time and provides data to the management party for dam safety construction and operation technology appraisal, and summarizes the operation experience. It can provide data basis for improving dam construction, operation mode, safety plan and project quality evaluation.

(3) Regularly compile the observation data and provide data for the construction of subsequent similar projects or the design, construction, management and scientific research of other similar buildings.

Schematic diagram of earth-rock dam monitoring project



Total station and prism
Settlement and surface monitoring

Video monitoring

GNSS
Surface displacement monitoring

Stationary Inclinometer
Displacement of depth soil mass

Vibrating Wire Piezometer

Throw in type water level
Reservoir water level monitoring

Weather station
Upriver rainfall monitoring

High frequency radar content gauge
length of dry breach

◆ Monitoring Items

SOUTH

The dam monitoring content is divided into the following aspects:

The main monitoring contents of dam monitoring include dam external deformation, seepage monitoring, dam internal monitoring, water level hydraulic monitoring and environmental factors monitoring. Generally speaking, dam surface deformation and seepage monitoring are the most important monitoring items.

A: External deformation monitoring : The main contents of external deformation monitoring include surface deformation, internal deformation, dam foundation deformation, crack joint change, concrete panel sliding Displacement of bank slope near the dam, etc.

B: Seepage monitoring: Seepage monitoring refers to the monitoring of seepage field generated under the action of upstream and downstream water level difference, mainly including seepage pressure, seepage flow and water quality change. Generally, for earth rock dams, it mainly includes dam foundation seepage, dam abutment seepage, dam body seepage, erosion seepage, etc. seepage monitoring mainly includes monitoring sections (dam foundation, dam body Determination of seepage pressure distribution and phreatic line position on structural sections such as seepage around dam on both banks.

C: Internal monitoring of dam body: Internal monitoring is generally not monitored separately, but synchronized with external deformation monitoring.

D: Water level hydraulic monitoring: As an important part of hydraulic engineering hub, reservoir dam water level hydraulic monitoring is particularly important. The main items of hydraulic water level monitoring include static water level monitoring , dynamic water pressure monitoring, water flow velocity, flow monitoring, etc.

◆ Monitoring Items

E: Environmental factors monitoring : mainly includes rainfall , air temperature, reservoir water temperature, sedimentation , etc. By monitoring the environmental factors , we can further grasp the variation law of environmental quantity and the correlation of its influence on dam deformation, seepage and stress. Generally, the environmental factors mainly monitors rainfall and temperature.

Different dam monitoring projects the monitoring items are different, but generally the same. The main monitoring items are as follows:

Monitoring Items	Monitoring Equipment
Surface deformation and displacement	GNSS
	Total station with prism
Meteorological	Weather station
Seepage	Water level
	Vibrating Wire Piezometer
Reinforced concrete stress	Vibrating wire type stress gauge，Thermometer
Overall change of dam	Video Monitoring System
	BIM modeling（Optional）

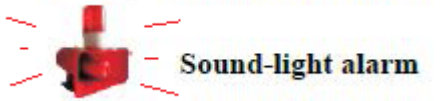
Monitoring Items	Monitoring Equipment
Internal deformation of DAM	Stationary inclinometer
Water level of dam	Radar water level
Dam incline	Tilt sensor
Uplift pressure	Uplift gauge
Crack	Crack meter
Soil pressure of dam	Soil Pressure Meter
Underwater topography	Unmanned Surface vessel(optional)

◆ The frame of Dam safety monitoring system

SOUTH

Data processing

3G 4G NB-Iot LoRa



Alert Application

Data transmission

4G 3G

3G 4G NB-Iot LoRa

DTU

Multi-channel Vibration wire signal collector

Data collection

RS485

Robotic total station

GNSS monitoring stations

Video Monitoring

Integrated weather station

Tilt senor

Stationary Inclinometer

Vibrating wire piezometer

Soil Pressure Meter(vibrating wire type)

Vibrating wire type crack gauge

Workflow

Monitoring Data

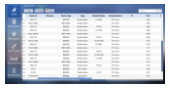
Manual Survey

Automatic monitoring

Semi-Automatic monitoring

Transmission

Server



Application

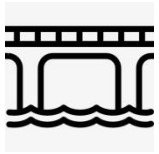
SMS E-mail APP

Sound and light alarm

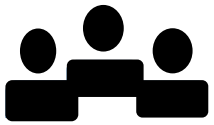
Web

Disaster control

Application Field



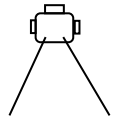
- Geological Disaster
- Bridge health
- Foundation Pit
- Dam safety
- Tailing Pond
- Highway Slope
- Tunnel



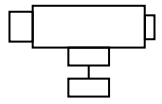
- Monitoring Units
- Construction Organization
- Natural resource Dept.
- Regulators
- Electrical power

Monitoring items Access

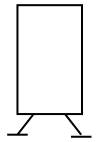
GNSS



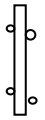
Robotic Total station



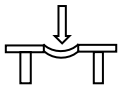
Electric level



Rain of environment

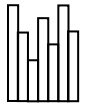


Inclinometer



Stress and strain

Crack



Vibration

◆ Dam external deformation monitoring

The deformation of dam surface and the displacement of bank slope near the dam are generally monitored by robotic total station or GNSS receiver. It is necessary to establish a deformation monitoring control network in the dam area to provide reference points for the robotic total station and GNSS receiver before the surface deformation monitoring activities. The control network can be an independent coordinate system or conjunction measurement with the existing geodetic control points. The control network must maintain regular retest (generally at least once every half a year) and correct the monitoring data distortion caused by the control network in time.

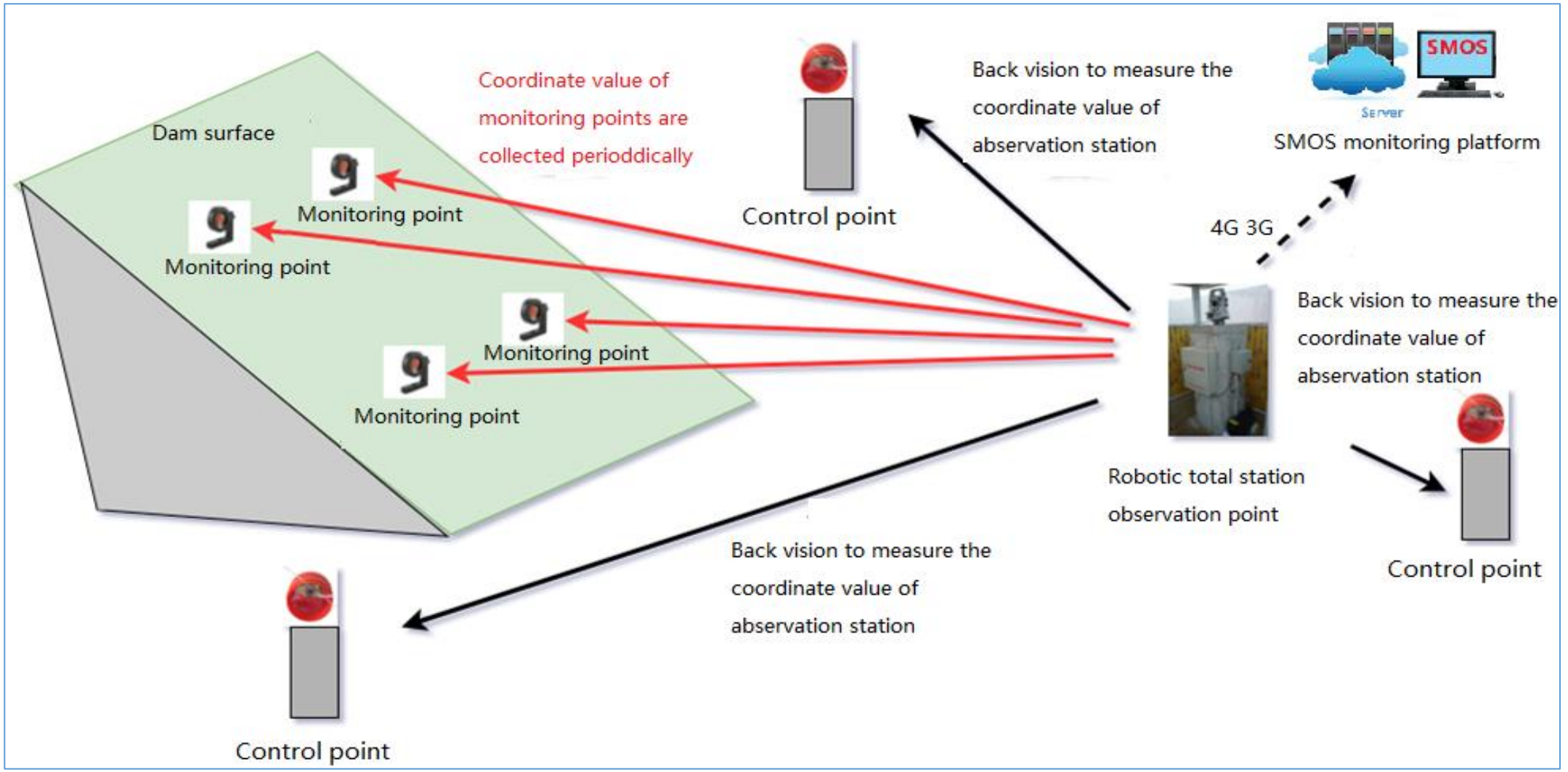
Survey principle of Total Station:

The principle of automatic monitoring of dam slope surface displacement by robotic total station is to set up prism at the dam slope surface monitoring point, select bedrock or build stable pillar outside the dam slope, fixed the total station, and select at least 3 stable control points outside the slope to form a control network. The robotic total collects and rear intersection observes at the control points through the automatic collection software, calculates the its coordinate value of observation station （total station） , and measures the monitoring points in a certain order. Through the pre-setting of the software, the total station can collect the coordinates of the monitoring points in the set cycle and collection sequence (before collecting the coordinates of the monitoring points each time, the coordinates of the control points shall be collected to ensure the accuracy of the coordinates of the measuring station itself). By comparing the previous coordinate value of each monitoring point, can calculate displacement status of monitoring point on the surface of dam slope to complete the automatic monitoring.

◆Dam external deformation monitoring

Total station

Principle of dam surface deformation monitoring by robotic total station



◆ Dam external deformation monitoring

Advantage of Robotic Total Station:

The robotic total station is an optical surveying and mapping instrument. The equipment only needs to maintain intervisibility with each monitoring point. The cost of increasing the monitoring point is only the price of prism or prism observation pillar. Therefore, in the case of small scope and large number of monitoring points, the robotic total station is a more economical way of surface monitoring. In addition, because only the robotic total station itself needs maintenance, the long-term operation cost is low. The robotic total station can run 24-hour continuous monitoring. Generally speaking, when the monitoring points are less than 100, the measurement period shall not exceed 1 hour, so it can obtain higher frequency data.

Observation station

Observation pillar

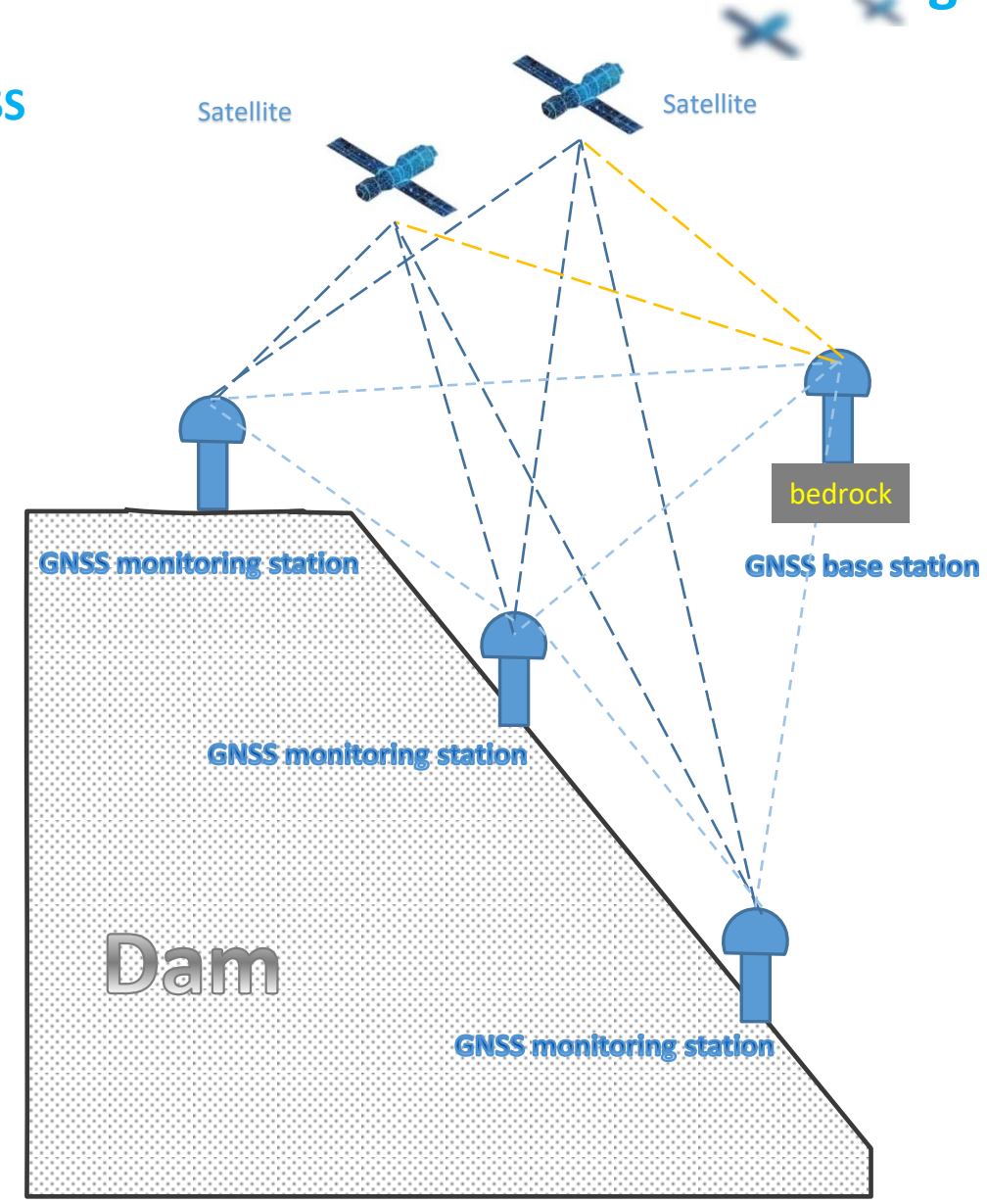
Monitoring point（prism）

Observation station

Special observation house

◆Dam external deformation monitoring

GNSS



The principle of dam surface deformation monitoring by GNSS

Survey principle of GNSS：

Principle of GNSS surface displacement monitoring: two GNSS stations A and B have observed the same group of satellites (at least 4 satellites) in the same period. If point A is a known point (with accurate coordinates), calculate the distance correction data from point A to the satellites and broadcast the correction data to B in real time, then point GNSS B receives the correction data from base A while observing GNSS, The positioning result of GNSS station B is corrected to obtain more accurate coordinate value.
Or the reference station and monitoring station send the observation data in each fixed period to the control center, and then the monitoring system calculates the coordinates of each monitoring station in each period, saves the three-dimensional coordinates of each monitoring point to the database, compares them with the basic coordinate data of each monitoring point, and the data analysis software automatically analyzes the change amount and trend of each monitoring point, and the stability of the dam is analyzed in combination with other monitoring equipment.

◆ Dam external deformation monitoring

GNSS monitoring stations

Advantage of GNSS:

Compared with the traditional optical measurement, GNSS has the ability to operate under all-weather conditions. Without being affected by bad weather. Without intervisibility condition between monitoring points, just through the sky. Therefore, it can be used in the environment with complex geological and meteorological condition. The integrated GNSS monitoring equipment has the advantages of high precision, low power consumption, high cost performance and more convenient installation. Therefore, GNSS can be used for surface displacement monitoring in the case of large dam monitoring range, complex dam structure and small number of monitoring points.

◆ Dam external deformation monitoring

Dam surface inclination and crack monitoring

Under the action of internal and external forces for a long time, some main structures of earth rock dam and concrete dam will incline or crack to a certain extent. At this time, it is necessary to use the tilt sensor and crack gauge to monitor the inclination and crack.

Tilt sensor

Crack gauge

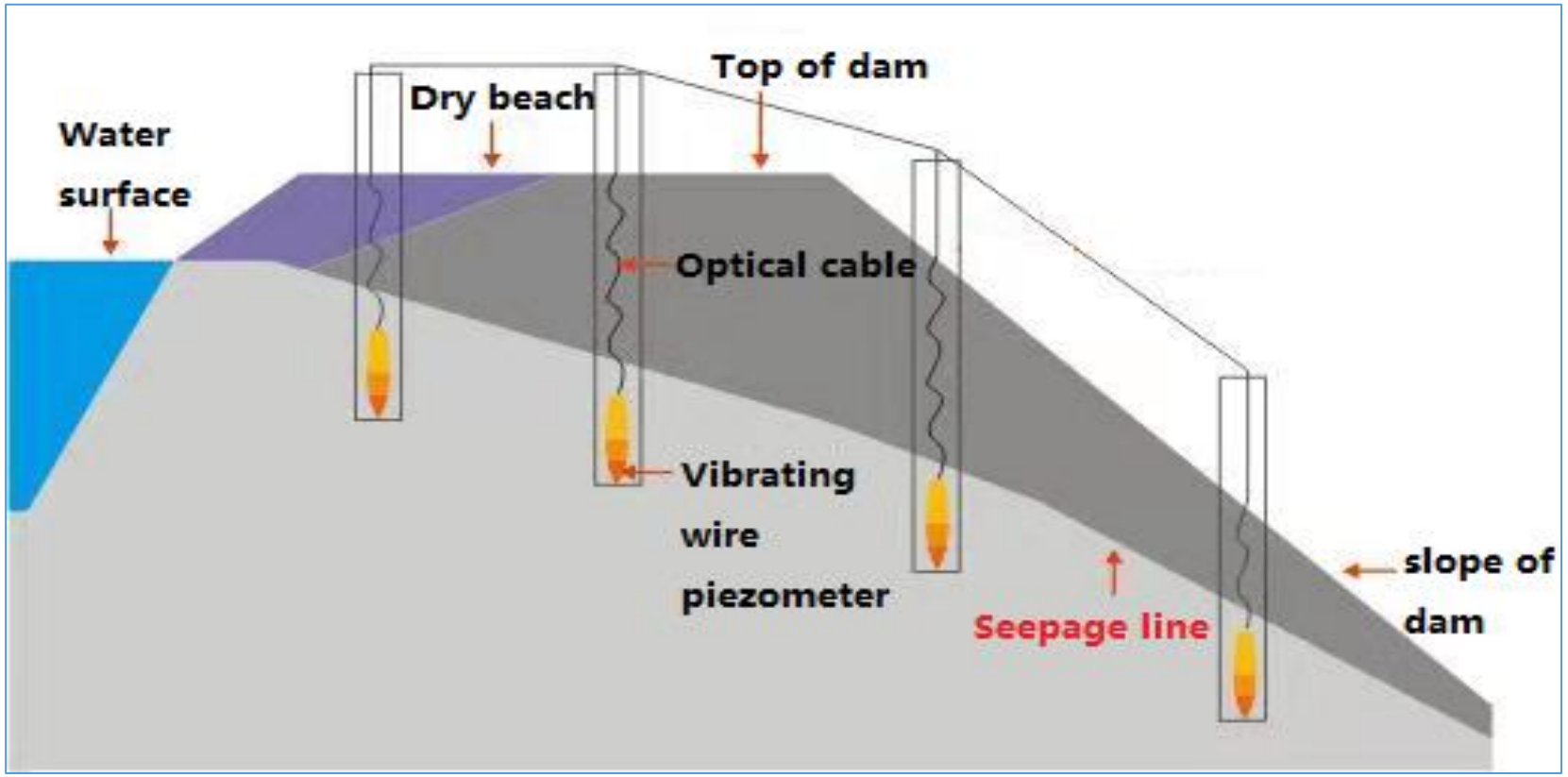
◆ Dam external deformation monitoring

Overall change monitoring of dam body

The performance characteristics of video monitoring alarm: real-time display monitoring image, single channel adjustment function of video image quality, separate setting of video speed of each channel, rapid retrieval, setting function of multiple video modes, automatic backup, pan-tilt control function, network transmission, etc. At present, in market some video monitoring image algorithm can even monitor the surface changes of the monitored object to a certain extent. Therefore, in dam monitoring, video monitoring can also be used as an auxiliary measure for surface change monitoring, which complements GNSS and total station in macro and micro aspects.

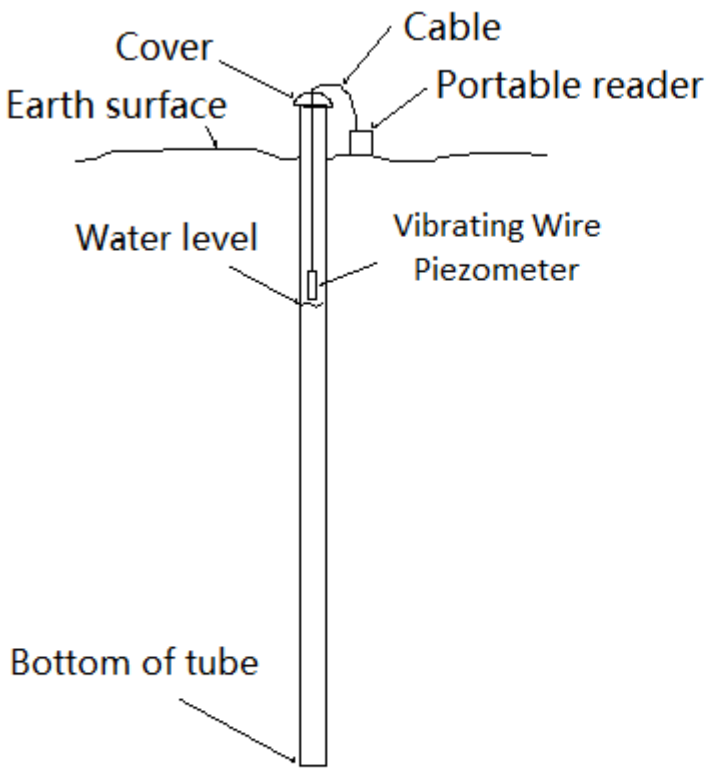
◆ Seepage monitoring

Seepage often occurs in the dam body and dam foundation due to action of upstream and downstream water level, after the impoundment of reservoir it becomes more obvious, which has an important impact on the stability of dam. Due to the limitations of designers' understanding of objective laws, seepage calculation and anti-seepage measures considered are often not perfect. Abnormal seepage phenomena beyond the design are often found in practical engineering cases. The accidents caused by seepage account for about 40% of all dam accidents. Therefore, seepage monitoring is the core activity of dam safety monitoring.

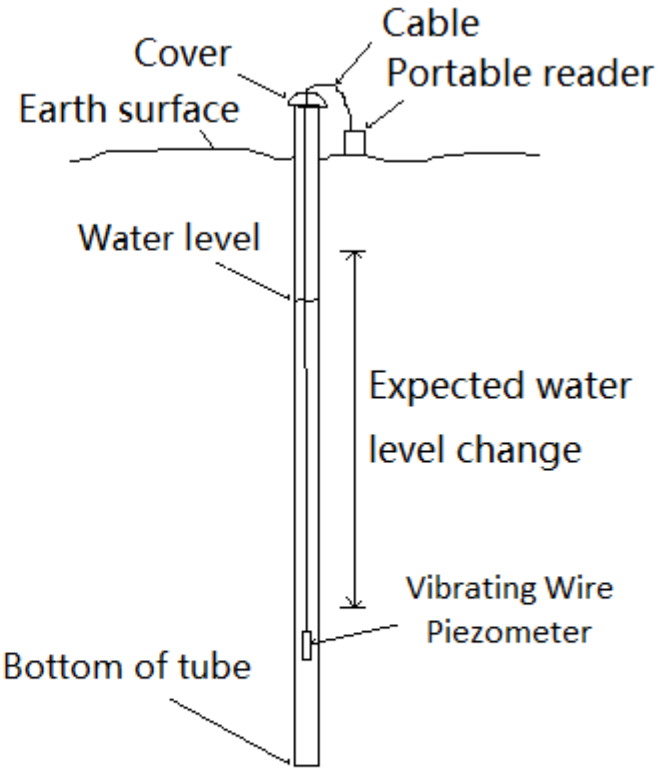


◆ Seepage monitoring

The schematic diagram of installing vibrating wire piezometer



Zero reading

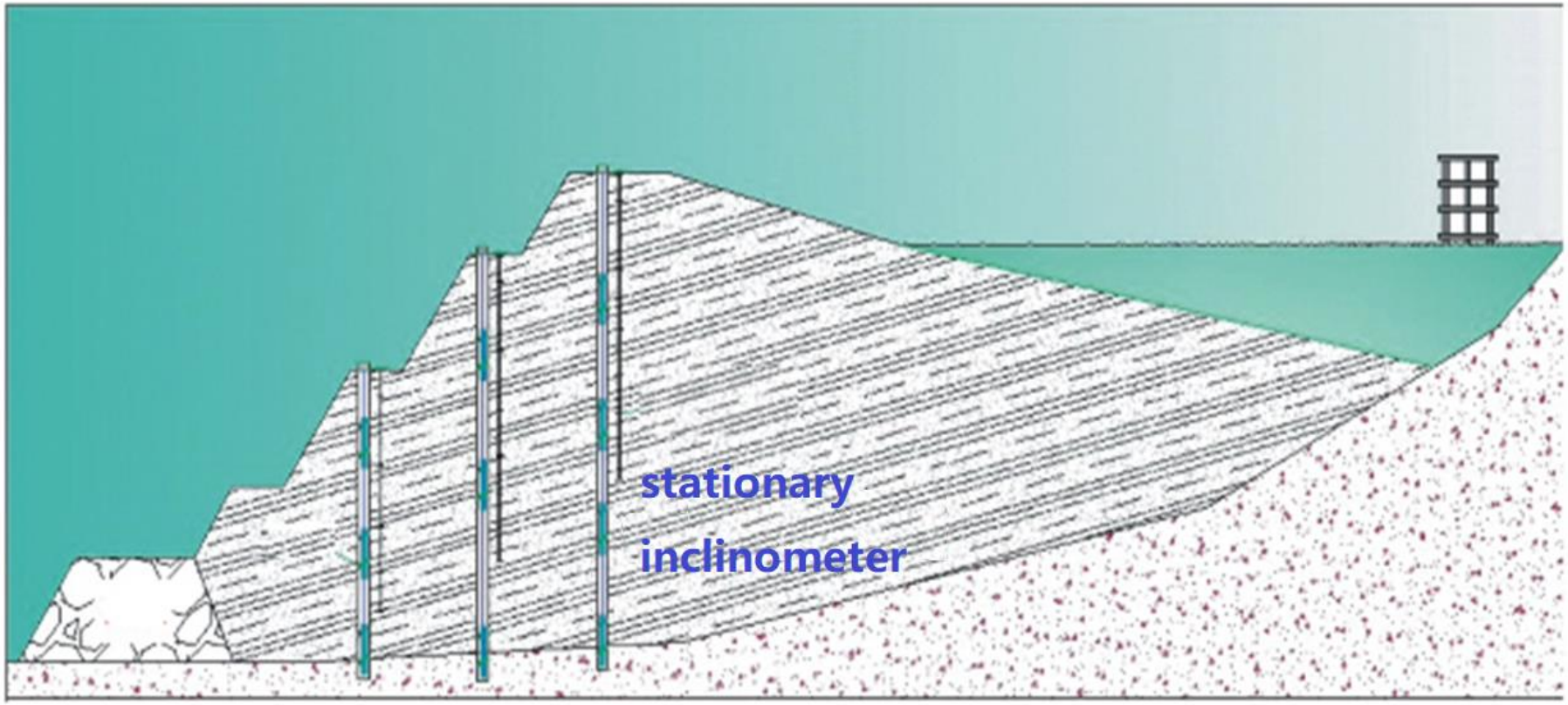


Typical installation

◆ Dam Internal monitoring

In the long-term operation stage of the dam, due to the influence of storage capacity pressure, its own structural pressure, rainfall, vibration and other factors, slow and continuous internal structural changes will occur, resulting in the deformation of the internal foundation of the dam. This deformation is the root cause of the external deformation, so it is necessary to monitor the inclination inside the dam, It plays an extremely important role in reflecting the foundation stability of the dam and predicting the occurrence of disasters in the later stage.
Generally, stationary inclinometers or flexible inclinometers are used to monitor the displacement of the internal structure of the dam.

Stationary inclinometer



Soil pressure monitoring of earth rock dam

Contact earth pressure monitoring refers to the monitoring of earth pressure on the contact surface between concrete, rock and soil. The purpose of contact earth pressure monitoring is to understand the magnitude, distribution and change of earth pressure borne by rigid buildings, analyze whether the buildings are safe, verify the design and provide basis for maintenance and repair. For earth rock dams, the pressure in the earth is generally monitored. Vibrating wire Soil Pressure Meter is generally used for earth pressure monitoring.

Vibrating wire Soil Pressure Meter

◆ Dam Internal monitoring

Concrete stress and strain monitoring

The concrete will produce strain under the influence of pressure, temperature and other factors, which belongs to micro changes. However, the concrete strain of the overall dam structure will lead to cracks on the concrete surface of the dam body and even internal cracks, which will seriously affect the stability of the dam structure. Embedded concrete strain gauges are generally used to monitor the stress and strain of concrete. For concrete panel monitoring, two groups are generally installed, one along the dam slope and the other in the horizontal direction. For internal stress and strain, strain gauge group can be used for monitoring. For the dam structure just completed, it is generally necessary to install concrete stress-free barrels simultaneously to eliminate the impact of its own concrete strain on the monitoring results.

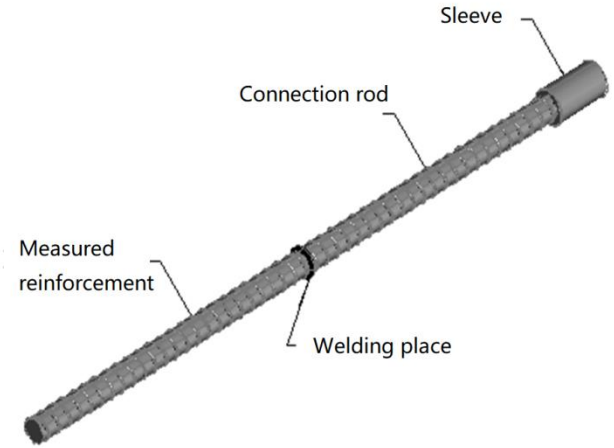
Vibrating wire strain gauge

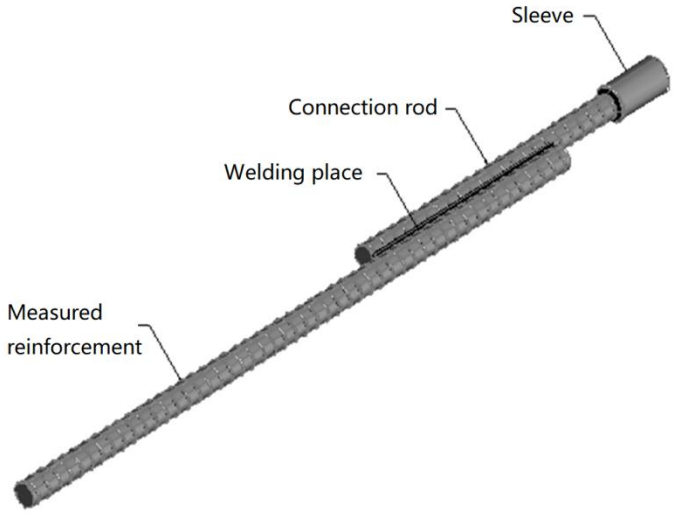
Strain gauge group

Stress strain monitoring of Reinforcement and anchor rod

The reinforcement meter is generally embedded in the dam structure or other concrete structures for a long time to measure the reinforcement stress of the internal structure of the dam structure. The reinforcement meter can synchronously monitor the temperature of the embedding point. For dam monitoring, anchor dynamometer, bedrock stress meter and other equipment can be formed by adding different accessories.

Vibrating wire Reinforcement meter





The connection mode between Reinforcement meter and measured reinforcement

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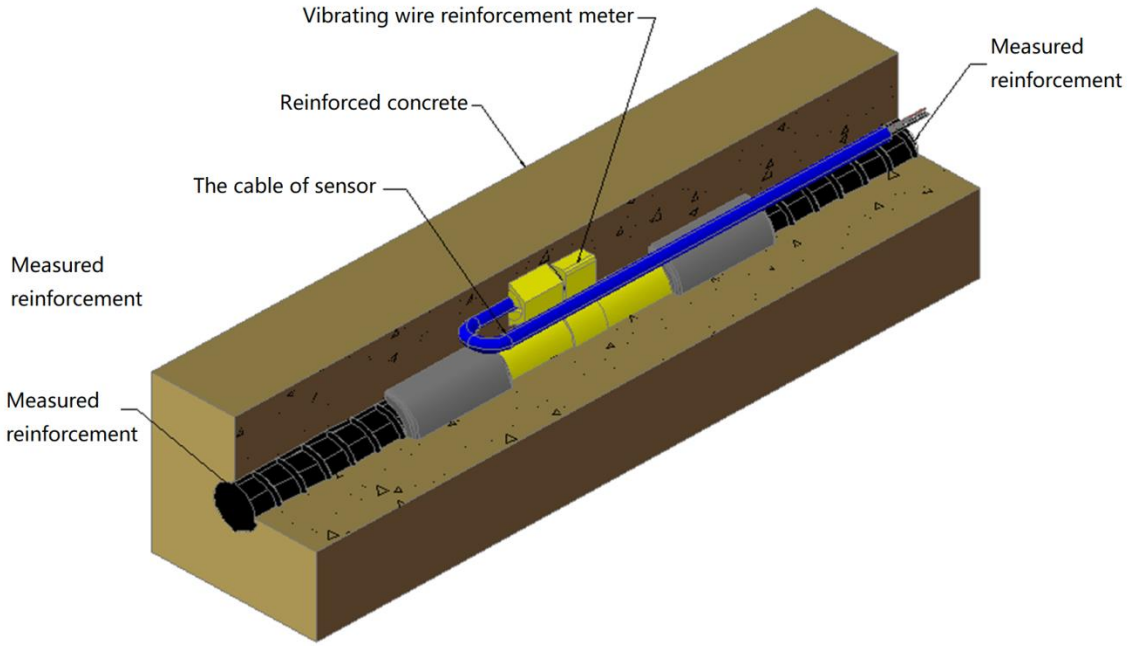
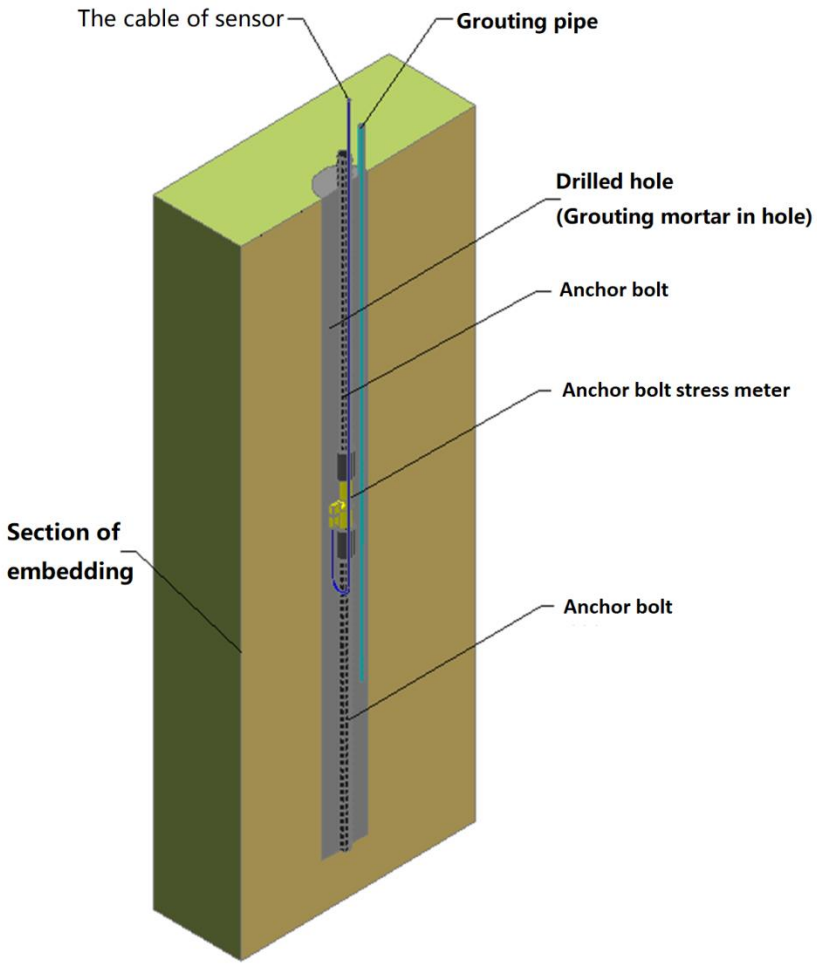
Schematic diagram of embedding reinforcement meter and anchor bolt stress meter





◆ Water level hydraulic monitoring

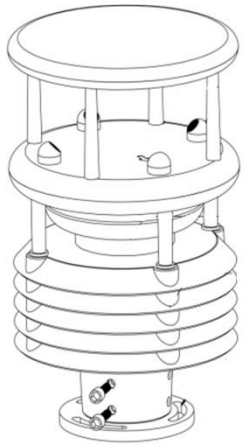
As an important part of water conservancy facilities, the monitoring of reservoir capacity, water level, flow velocity and discharge in the dam area is very important for flood control, disaster reduction and hydropower generation in this area. Therefore, an all-weather water level monitoring system should be established in the dam area. It mainly includes: upstream and downstream water level monitoring of the dam; Dam velocity monitoring, etc. Water weir gauge, radar water level gauge and other equipment can be used for water level monitoring, and ultrasonic flowmeter can be used for flow rate monitoring.

Radar water level gauge, also known as water level radar, is an electronic device that uses electromagnetic wave to detect targets. Generally, it includes transmitter, transmitting antenna, receiver, receiving antenna and other components. Its main function is to carry out water conservancy monitoring, sewage treatment and flood control early warning. The main measurement principle is that the radar pulse is transmitted from the radar water level sensing antenna, the antenna receives the pulse reflected from the water surface and records the time T. since the propagation speed c of electromagnetic wave is a constant, the distance d to the water surface is obtained

Radar Water level

◆ Environmental factors monitoring

Environmental factors such as rainfall and temperature will also affect the stability of the dam structure under certain circumstances, especially when the water level rises sharply due to rainstorm in summer, it will have a very obvious impact on the storage capacity, water pressure and water level inside the dam. Multi parameter meteorological station is generally used for environmental monitoring.



Integrated 6-parameter meteorological station

Installation example of Meteorological Station

◆ Related Equipment

Vibrating wire crack gauge

Hydrostatic Level

ADM

DTU

Multi-channel Vibrating wire signal acquisition

Automatic deformation monitoring solution

South deformation monitoring system is a fully automatic monitoring system based on advanced IOT technology, which is compatible with conventional monitoring solutions. It can achieve real-time and effective dynamic analysis and safety early alert of the monitoring target by various means, improve the accuracy and credibility of the monitoring data while reducing the workload of personal.

Solved pain points that man-made more factors in conventional monitoring and automatic monitoring.

Using sensors to monitor the targets (include geologic disasters, highway & railway slope, foundation pit, dam safety, trailing pond, bridges health, tunnel…etc.) for all-weather automatic real-time monitoring. Transmit all status and data of monitoring targets to the data processing center in real time by various wired or wireless network technology. To complete analysis, judgment, alert. Terminal devices can passively receive the alert information, also can actively log in the platform to acquire various status and data of monitoring targets, which is the basis for decision-making.

Road Slope Monitoring

Geological Disaster monitoring

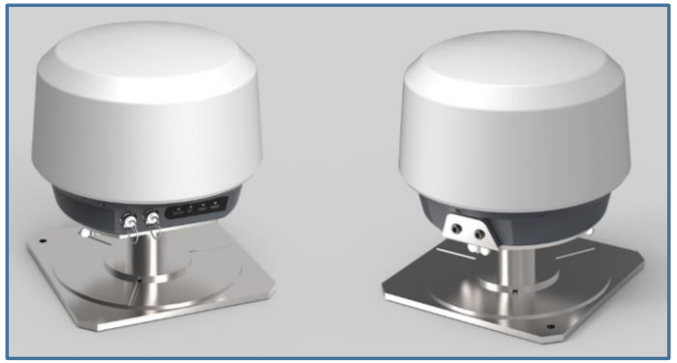
Dam Monitoring

Tailings pond Monitoring

Foundation Pit Monitoring

Bridge health Monitoring

◆GNSS Monitoring station



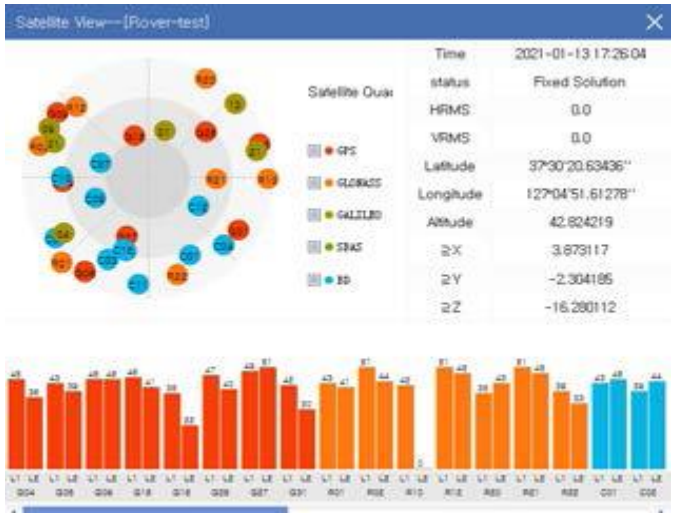
SOUTH Model: MR1

Integrated Design | High Accuracy | Low-power Consumption | Remote Control

Anti-Steal Design | Multiple Communication | Cloud Service | IP68

- General applicability monitoring GNSS
- Optimization Algorithm
- Monitoring Accuracy 1mm/ 24 hours in short baseline

● Stable and high accuracy GNSS monitoring engine and dual independent GNSS process algorithms



● Real-time and history data and graphic view, report data export

◆GNSS Monitoring station

GNSS monitoring station MR1

MR1 is a special purpose model for deformation monitoring.

As the general applicability equipment, MR1 is widely applied to monitor for the displacement of earth surface. Usually, MR1 base station is built on a stable bedrock which near by monitoring stations, monitoring stations are built on the risk slopes.

With stable and high accuracy GNSS monitoring engine and dual independent GNSS process algorithms, it can automatically and continuously monitor the slopes status for every second, the precision coordinate values can be calculated according to your interval settings.

Install on disaster site

◆GNSS Monitoring station

SOUTH

MR1

- Multi-frequency and Multi constellations GNSS board
- Integrated Design easy to install
- Low-power Consumption
- 3G/4G network unit
- Internal battery
- Bluetooth, WIFI
- WebUI
- Remote control
- magnesium aluminum alloy housing
- IP68

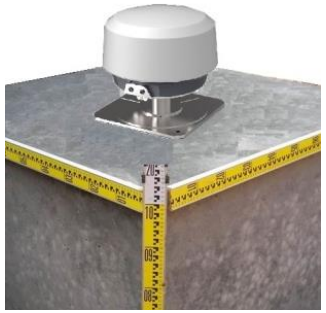
NET S10 mini

- Multi-frequency and Multi constellations GNSS board
- Support high speed network
- Bluetooth WIFI
- Support 5 independent data streams transmission
- Low-power Consumption
- Internal radio (option)
- Remote control
- magnesium aluminum alloy housing
- IP68

NET S10

- Multi-frequency and Multi constellations GNSS board
- 3G/4G network unit
- Bluetooth/ WIFI
- Support multiple data format
- Internal battery
- LCD screen
- Support connection weather station and tilt sensor
- Built in 13000mAH battery
- IP68

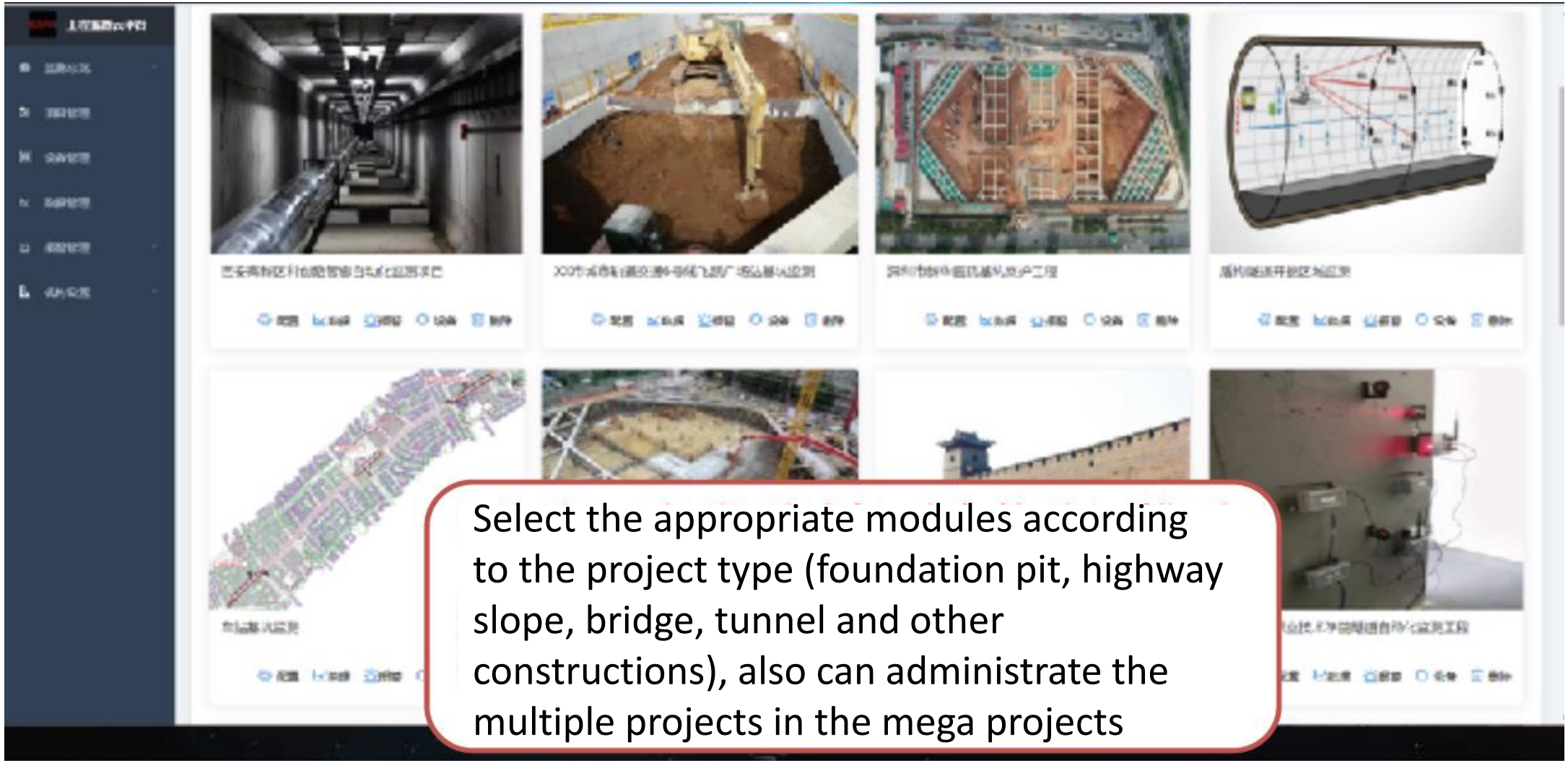
◆Installation



Install on observation pillar

Install on stand column

◆SMOS Different Modules

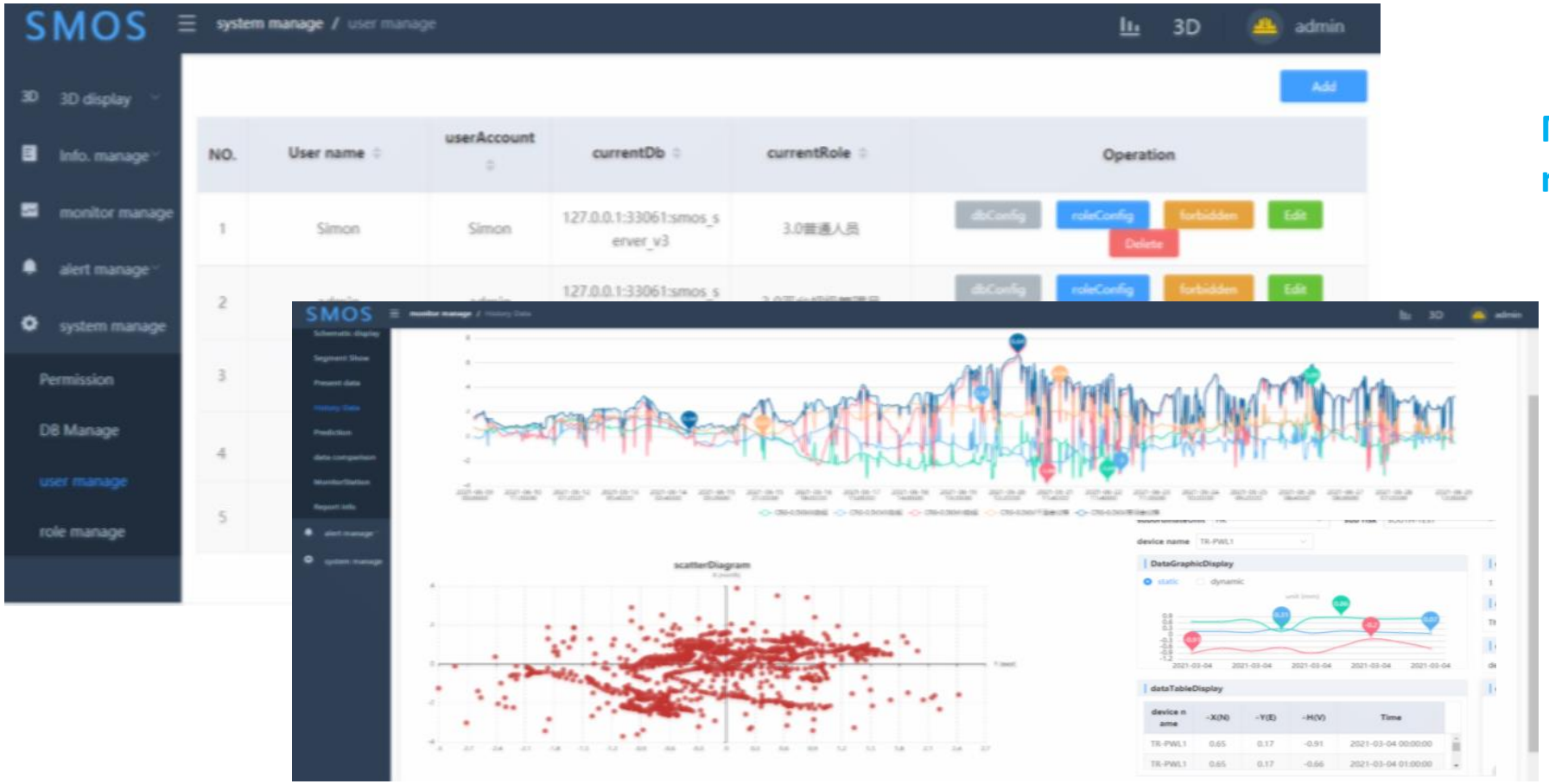


Select the appropriate modules according to the project type (foundation pit, highway slope, bridge, tunnel and other constructions), also can administrate the multiple projects in the mega projects

Software South monitoring system (SMOS)

SMOS software includes different functional modules to meet the user's demand, geological disaster, highway & railway slope, foundation pit, dam, trailing pond, bridge health, tunnel…etc.

◆ Software interface

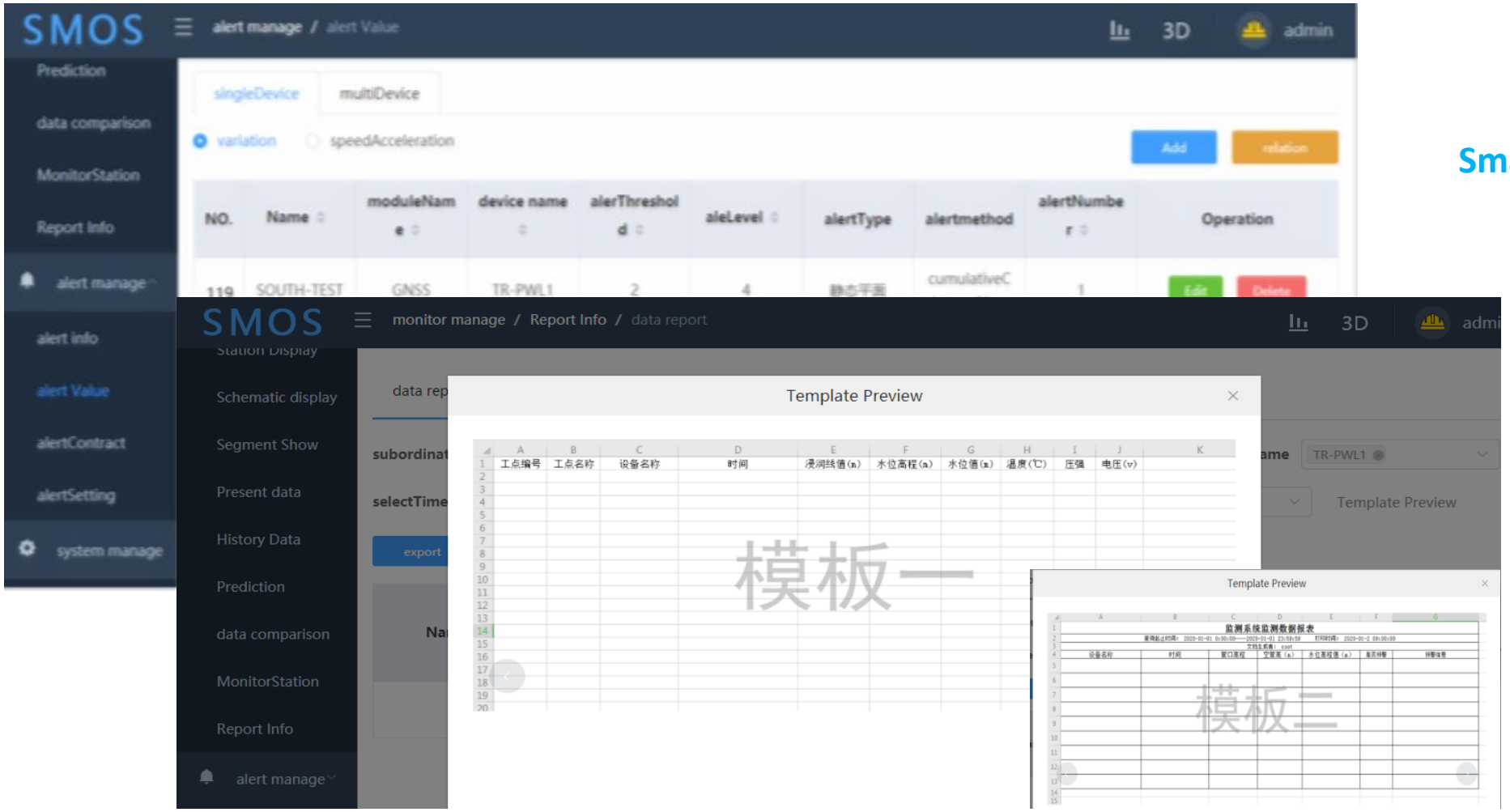


Multi-user management

Powerful Data analysis and chart show

Software South monitoring system (SMOS)

◆ Software interface



Smart alert model

User define report export