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Real-Time Monitoring of Meteorological Data at *In-Situ* GCW Remediation Sites

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Abstract

To optimize the self-organization network, self-adaptation, real-time monitoring, remote management capability, and equipment reuse level of the meteorological station supporting the portable groundwater circulation wells, and to provide real-time and effective technical services and environmental data support for groundwater remediation, a real-time monitoring system design of the meteorological station supporting the portable groundwater circulation wells based on the existing equipment is proposed. A variety of environmental element information is collected and transmitted to the embedded web server by the intelligent weather transmitter, and then processed by the algorithm and stored internally, displayed locally, and published on the web. The system monitoring algorithm and user interface are designed in the CNWSCADA development environment to realize real-time processing and analysis of environmental data and monitoring, control, management, and maintenance of the system status. The PLC-controlled photovoltaic power generating panels and lithium battery packs are in line with the concept of energy saving and emission reduction, and at the same time, as an emergency power supply to guarantee the safety of equipment and data when the utility power fails to meet the requirements. The experiment proves that the system has the characteristics of remote control, real-time interaction, simple station deployment, reliable operation, convenient maintenance, and green environment protection, which is conducive to improving the comprehensive utilization efficiency of various types of environmental information and providing reliable data support, theoretical basis and guidance suggestions for the research of groundwater remediation technology and its disciplines, and the research and development of the movable groundwater cycling well monitoring system.

Keywords

Groundwater Circulation Well, Weather Station, Real-Time Monitoring, Embedded Web Server

1. Introduction

Groundwater circulation well technology, or GCW, is a developing *in situ* remediation technology that can remove contaminants from groundwater and saturated soil (Song, Yue, Li, & Zhong, 2022). The remediation system mainly consists of a nested combination of inner and outer wells, surface or in-well aeration equipment, extraction pumps, gas injection pumps, above-ground gas treatment equipment, sensory monitoring equipment, and other auxiliary equipment. At present, the current status of groundwater pollution in China is regionally prominent, the pollution of key areas has intensified, the impact of typical pollution fields has increased significantly, and the sources of pollutants have gradually increased (Ma & Yan, 2019), however, China's groundwater cycling wells technology and supporting systems are still in the initial stage of research, and it will take a certain amount of time before they are put into practical application (Xu, Sun, Li, Zhang, & Zuo, 2020), in which the environmental conditions in which the groundwater cycling wells are located on the groundwater remediation technology and system electronic equipment work. The prominent influence and limitation of the condition of groundwater circulation wells need to be further researched (Yin, 2018; Lv, 2016), therefore, the accuracy and real-time requirements for monitoring of environmental elements have been raised more and more.

In recent years, unmanned automatic weather stations as a new type of meteorological data acquisition and processing program are being vigorously developed in combination with communication technology, embedded systems and Internet of Things (IoT) technology, and the combination of meteorological element sensors with low power consumption, small size, embedded system kernel with rich integrated interfaces, convenient data transmission and storage, and IoT devices with flexible networking and expansion to form a new generation of intelligent meteorological monitoring system has become a hot spot of research (Hang, Zhang, & Xu, 2017). At present, there are a variety of automatic weather station monitoring system designs combining the Internet, cloud server and other technologies (Gong, Ma, Huang, Sun, & Yuan, 2014; Huang, Tan, & Huo, 2022; Ma, Ma, & Liu, 2016; Huang & Tang, 2020), although observation automation is realized to a certain extent, there are still problems such as difficulty in networking, insufficient degree of intelligence, inconvenience in system management and updating the small amount of data transmission and storage, and low level of remote real-time monitoring, etc., which is difficult to meet the growing needs of enterprises and institutions that are closely related to the meteorological elements for the use of meteorological data. It is difficult to meet the ever-increasing demand for meteorological data from enterprises and institutions closely related to meteorological elements. Therefore, it is of great significance to develop a new type of real-time monitoring system for Internet of Things (IoT) weather stations with high intelligence, self-organizing network, self-adaptation, real-time monitoring, and remote management for groundwater circulation wells.

This paper integrates IoT technology with existing meteorological station monitoring systems to design a real-time monitoring system for portable groundwater circulation wells. The system uses an embedded Web server for networking, monitoring, and collecting environmental data. It supports remote access via smartphones and computers, enhancing efficiency in environmental data utilization. Photovoltaic panels and lithium batteries improve energy efficiency and emergency capabilities, ensuring equipment and data safety. The system reduces equipment costs and provides reliable support for groundwater remediation research.

2. Overall System Design

The overall structure of this system is shown in Figure 1 and consists of the following five main parts:

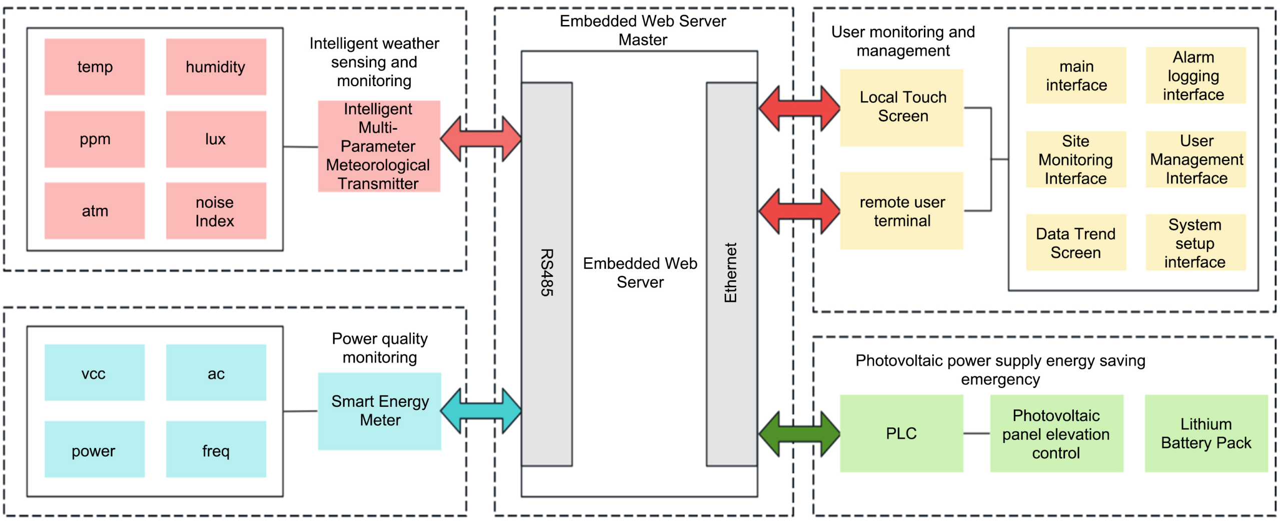


Figure 1. System function block diagram.

1) Intelligent meteorological sensing and monitoring part: The intelligent multi-factor meteorological transmitter integrated with a variety of meteorological element sensors collects environmental information such as temperature, humidity, carbon dioxide concentration, light intensity, atmospheric pressure, noise value, etc., and transmits it to the embedded Web server;

2) Embedded Web server main control part: Embedded Web server as the hub of the system, not only will receive the environmental data processed by a specific algorithm for internal storage, local touch screen display, and Web publishing, but also with the monitoring, control, management, maintenance, updating of the entire system, and can quickly react to the abnormal conditions of the alarm notification;

3) User monitoring and management part: Users can remotely access the embedded Web server in real-time via the Internet through terminals such as cell phones or computers to understand and control the system in the form of text, animation, trend curve, and so on;

4) Power quality monitoring part: to ensure the reliability of the system power supply, the use of smart meters to implement the system power supply monitoring;

5) Photovoltaic power supply energy-saving emergency part: PLC-controlled photovoltaic power generation panels can be converted into light energy to the system power supply or charged to the standby lithium battery packs, at the same time, when the utility power fails to meet the requirements or even failures, and lithium battery packs can be coordinated with the emergency power supply to ensure that the entire system, to protect the safety of equipment and data.

3. Hardware

3.1. Intelligent Multi-Element Weather Transmitter Selection

Intelligent multi-factor meteorological transmitter chooses RS-BYH-CO2-M meteorological multi-factor shutter box. The weather transmitter adopts a 10 - 30 V wide voltage DC power supply, standard ModBus-RTU communication protocol, and RS485 signal output. Internal integration of temperature, humidity, carbon dioxide, light, barometric pressure, and noise six elements of the sensor, the environmental elements of the measurement range and measurement accuracy for Temperature measurement range −40˚C - +120˚C, measurement accuracy ± 0.5˚C (25˚C); humidity measurement range 0% RH ~ 99% RH, measurement accuracy ± 3% RH (60% RH, 25˚C); carbon dioxide concentration measurement range 0 - 5000 ppm, measurement accuracy ± (40 ppm + 3% F-S) (25˚C); light intensity measurement range of 0 - 200,000 lux, measurement accuracy ± 7% (25˚C); atmospheric pressure measurement range 0 - 120 kPa, measurement accuracy ± 0.15 kPa (25˚C, 75 kPa); Noise measurement range 30 dB - 130 dB, measurement accuracy ± 3 dB, key components imported devices, stable and reliable, with a wide measurement range, good linearity, good waterproof performance, easy to use, easy to install, long transmission distance and so on.

3.2. Embedded Web Server Selection

According to the needs of environmental data transmission, processing, storage, and the whole system monitoring, control, management, maintenance and updating, the embedded Web server needs to have high computing speed and allow algorithmic programming for real-time processing of environmental data, support for ModBus-RTU/TCP communication protocols, have a large capacity of internal storage, and at the same time, also have the ability of Web publishing. Therefore, the system chose CBL410G Kusoft Cloud Box as the control core of the system, the model of the Cloud Box with a 4-core 1.4 GHz high-performance core processor, 512M RAM, and 8 G storage, including three RS485 interfaces, an RS485/232 interface, two Ethernet interfaces, built-in a set of embedded configuration software, support 4G, Python, Web Publishing, remote download, WeChat alarm, map and video, support historical data/historical alarm, support uploading to AliCloud IOT platform, and can backup data to MySql, SqlService and other servers.

3.3. Smart Energy Meter Selection

The intelligent power meter is crucial for detecting the degree of good and bad power supply of the system, so the Kunlun DTSU666 model three-phase four-wire electronic power meter was chosen. The meter uses large-scale integrated circuits, the application of digital sampling technology, the three-phase voltage, three-phase current, active power, reactive power, frequency, forward and reverse power, four-quadrant power, and other parameters of the electrical line for real-time measurement and display, with RS485 communication interface, support for ModBus-RTU communication protocols, the reference voltage of 3 × 220/380 V, the current specification 1.5 (6) A, pulse constant 6400 imp/kWh and 6400 imp/kvarh, active accuracy 0.5S level, reactive accuracy 2 levels, specified operating temperature range −10˚C - +45˚C, limit operating temperature range −25˚C - +70˚C, with better technical performance and parameter indicators, can fully meet the system requirements for power supply quality monitoring.

3.4. PLC Selection, I/O Allocation, and Wiring

As the ModBus-TCP server, the external electromechanical equipment controller controlling the starting and stopping of the lifting motor of the photovoltaic power generation panel, the PLC chooses the domestic high-performance and highly reliable AMX-200 series PLC 224XP-E v21.06 AC/DC/RLY. The PLC adopts advanced digital control technology and high-efficiency power electronics, which can realize automated control of all kinds of industrial equipment and production lines. The PLC adopts advanced digital control technology and highly efficient power electronic devices to realize automation control of various industrial equipment and production lines. It has built-in 16 K program memory and 10 K data memory, 14 digital input points, 10 digital output points, 2 RS485 standard PPI communication interfaces, and 1 channel 100M Ethernet interface, and it supports a variety of communication protocols so that it can be networked and communicated with other equipment and systems to realize a comprehensive and integrated control.

Table 1. I/O port allocation of PLC.

	Name	Ports	ModBus Address	Note
Output signal	Control Module 1	Q0.0	16	Generator board 1 raise control
	Control Module 2	Q0.1	17	Generator board 1 descent control
	Control Module 3	Q0.4	20	Generator board 2 raise control
	Control Module 4	Q0.5	21	Generator board 2 descent control

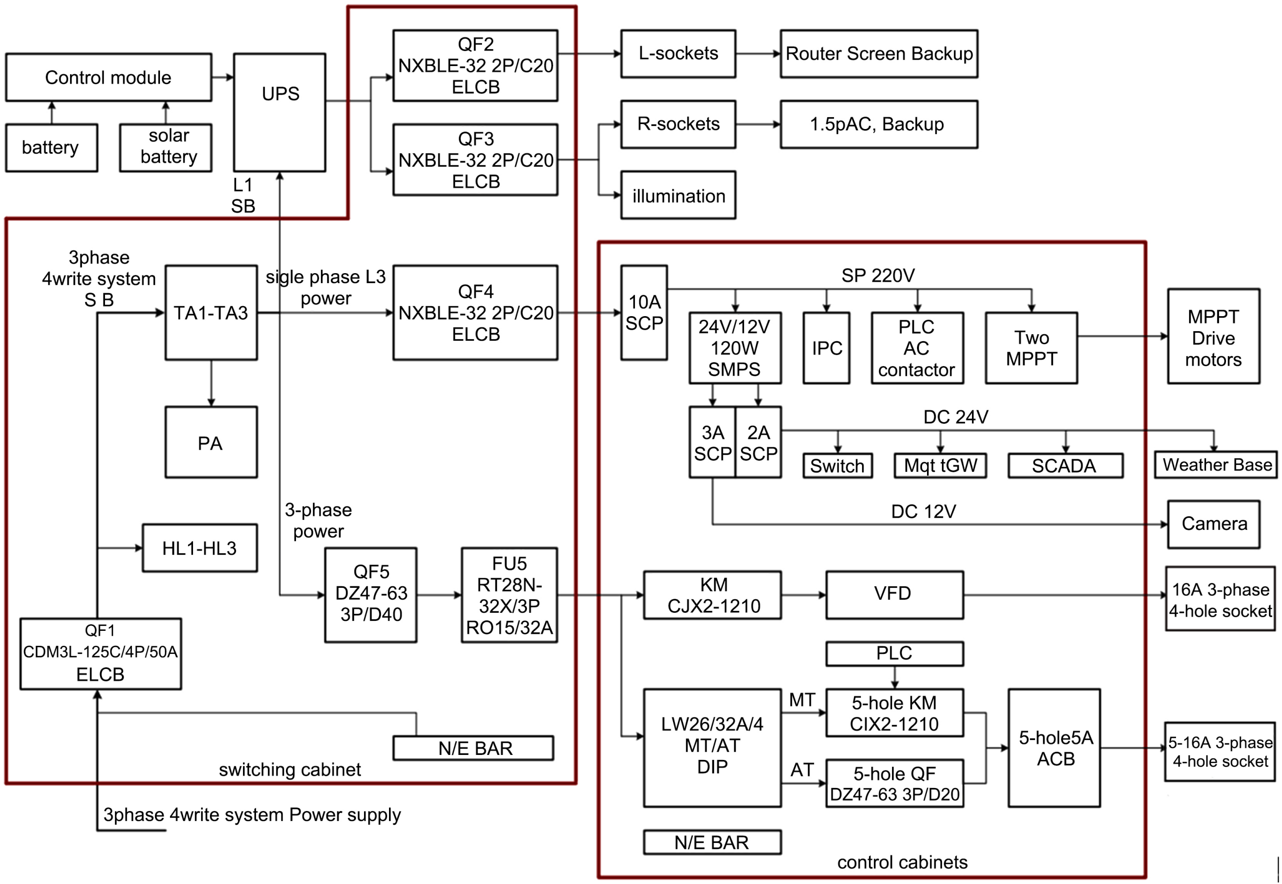


Figure 2. GCW integrated equipment control system.

The digital outputs of the PLC are assigned I/O ports as shown in Table 1 and labeled with the ModBus protocol address corresponding to each I/O soft component.

According to the existing equipment configuration of removable groundwater circulation wells, an external expansion I/O board EM222-1HH22-OXAO is connected to the PLC expansion board and related equipment by the I/O port assignments in Table 1, and the wiring diagram is shown in Figure 2.

3.5. System Communication Wiring

According to the needs of system communication interaction, the communication line between each device and the embedded Web server is divided into two parts: RS485 bus and Ethernet line. The smart weather transmitter and smart energy meter use RS485 bus with ModBus-RTU communication protocol to transmit data, and the baud rate is set to 9600 bps, no parity bit, and 1 stop bit by using the supporting software, in which the embedded Web server is the master, the weather transmitter is the No. 1 slave, and the smart energy meter is the No. 2 slave, and the PLC and the local touch screen use Ethernet line with ModBus-TCP communication protocol to transmit data, and the embedded Web server, the weather transmitter, and the smart energy meter are respectively divided into two parts.

The PLC and the local touch screen use ModBus-TCP communication protocol to transmit data over an Ethernet cable. The embedded Web server, PLC, and touch screen are assigned different IP addresses under the same network segment, the embedded Web server is assigned the IP address 192.168.1.77, the PLC is assigned the IP address 192.168.1.88, and it is set to the ModBus-TCP server mode, and the touch screen is assigned the IP address 192.168.1.88. IP address 192.168.1.99 for the touch panel.

3.6. Photovoltaic Power Panel Elevation Motor Drive Selection

The PV power panel lift motor driver is used to drive the frequent starting and stopping of the lift motor of the PV power panel, which not only needs to have continuous and stable load-carrying capacity, but also needs to have multiple protection measures, so we choose YH-A290020-E motor linear driver. The driver adopts switching control, which can convert the input 100 - 240 V 1.5A 50/60 Hz AC power into 29V 2.0A DC power stable output to drive the starting and stopping of the lifting motor, and at the same time, it has the protection functions of temperature protection, overload protection, and limit protection.

4. Software

4.1. Device Configuration

It is of great significance to utilize CNWSCADA (Network Edition) development environment software supporting embedded Web server to realize equipment configuration, which is aimed at indicating the hardware composition of the system, the type and connection mode of the communication link, writing the logic and algorithm of monitoring and control and drawing the human-machine interface according to the functional requirements, to enable the system to operate reliably, efficiently and persistently, and to provide all kinds of information required by the users, and to enable the users to manage and monitor the operation status of the system easily and quickly according to the information provided to maximize the efficiency. At the same time, it enables users to manage and monitor the operation status of the system easily and quickly according to the information provided and maximizes efficiency. Equipment configuration mainly accomplishes the following functions:

1) Create I/O communication mode and communication variables: According to the communication interaction type supported by each device of the system, establish two communication modes, ModBus-RTU and ModBus-TCP, configure each communication parameter, create the required variables under the two modes, and verify until the communication is successful.

2) Write system monitoring scripts: use JavaScript scripts to judge the validity of the collected environmental data and realize smooth filtering to enhance the authenticity and reliability of the data, use PLC to control the starting and stopping of the lifting motors of photovoltaic power generation panels for energy saving and emergency response according to the magnitude of the light intensity, and

according to other requirements to complete functions such as user management, realization of interface functions, acquisition of network time, acquisition of geographic information of the site, acquisition of real-time weather and other functions. Functions include acquisition, real-time weather data collection, and more.

3) Drawing the human-computer interaction interface: the interaction interface serves as a bridge for direct communication between the user and the system, and clearly and intuitively displays all kinds of information about the whole system, which can facilitate the optimization and management of the system by the user. Users can remotely query all kinds of environmental data and their trends in real-time and historical curves, historical alarm records and alarm settings, system status, etc., assign privileges to specific user identities, and provide a way to manage and control the whole system.

4) Setting alarm mode and alarm information: When part of the collected data exceeds its set limit, the system automatically analyzes the cause of the problem, generates alarm information and displays it in the specified interactive interface, and at the same time alerts the operator in a preset way, such as a micro-letter alarm, etc., to avoid accidents.

4.2. Data Acquisition and Processing Program Design

The functions of environmental data collection, conversion, judgment, processing, and control are mainly realized by the JavaScript script program running in the embedded Web server on the database side, and the program flow is shown in **Figure 3**. After power-on initialization, the embedded Web server judges whether to collect environmental information interactively with the intelligent weather transmitter according to the user's instruction; if not, it enters the standby mode and waits for the user's instruction; if it is needed, the server continuously sends ModBus-RTU read command packets to the weather transmitter with the pre-set collection cycle and receives the returned environmental data in turn, and judges the validity of the data after conversion; if the data exceeds the set validity, the data is converted into a database and processed by the embedded Web server. The data is converted and judged to be valid; if the data is out of the set valid range, it will be judged to be abnormal; if there is no abnormality, it means that there is interference, and it will be turned to data parsing; if there is an abnormality, it will generate an alarm report and send an alarm notification to the user in a set way; if it is in the valid range, it will be directly parsed through the packet, filtered and processed, and then it generates data frames in line with national meteorological norms for local storage and plotting of the environmental information. Trend curve interface display, Web publishing so that users can query remotely via the Internet in real-time.

Since the working environment of automatic weather stations is usually different and harsh, which may lead to large fluctuations in the collected data due to the disturbing influence of the sensors in the weather transmitter, processing the converted environmental data through the digital filtering method can effectively reduce the disturbance and improve the authenticity and reliability of the data. This system adopts the sliding mean filtering method, storing the three recently collected data of the same environmental element in the three variables of earlier data, recent data, and current data, and realizing the filtering processing of all data in the way of sliding average within the range of the number of valid data.

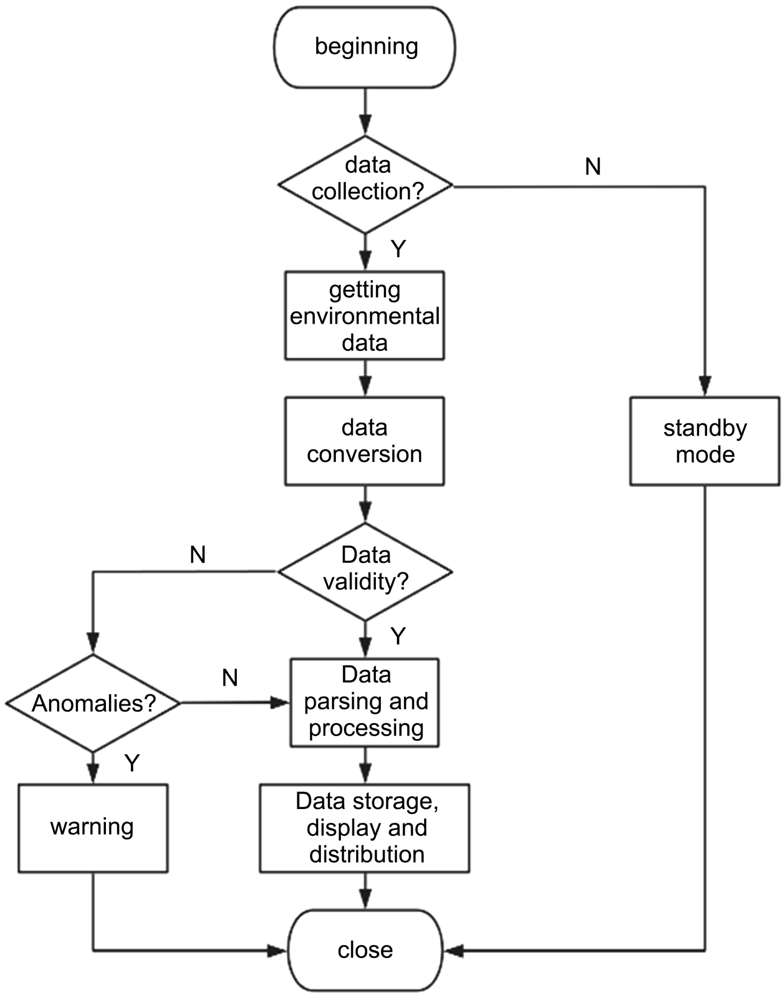


Figure 3. Flow of environmental data acquisition and processing program.

4.3. Alarm Record and WeChat Alarm Notification

According to the fluctuation level of each environmental element under normal and abnormal conditions, alarm-related parameters are set for each of them in the variable table, as shown in Table 2.

When environmental data is outside the set alarm limits and is judged to be abnormal, the system automatically generates alarm information in the alarm report, including alarm time, recovery time, variable name, alarm description, alarm group, alarm value, and alarm limit value. The alarm report also provides the functions of querying historical alarm records and real-time alarm records, clearing and exporting records, and modifying alarm limits.

Table 2. Alarm limits of each environmental factor.

variable name	Alarm Limits and Alarm Texts
Temp	low = −20|temp to low; low = −10|lower temp; high = 40|higher temp; high = 45|temp to high
Humidity	low = 10|humidity to low; low = 15|lower humidity; high = 90|higher; high = 95|humidity to high
Ppm (CO_2)	high = 20,000|higher ppm; high = 3000|ppm to high
Lux	high = 80,000|higher lux; high = 100,000|lux to high
Atm	low = 55|atm to low; low = 65|lower atm
dB (Noise value)	dB = 60|higher dB; high = 70|dB to high

Note: The units of each alarm limit are: 1) temp: ˚C; 2) humidity: RH; 3) CO_2 concentration: ppm; 4) light intensity: lux; 5) atmospheric pressure: kPa; 6) noise value: dB.

To notify users of alarm information in a timely and accurate manner, the function of WeChat alarm notification is designed. First of all, create enterprise WeChat for this system and create an alarm push application in its application management, then add the user who receives the notification into the enterprise address book and give the application privileges, and finally fill in the CorpID, AgentID, and Secret of the enterprise The WeChat in the alarm configuration of the development environment software of CNWSCADA (network version), write the alarm notification message format, and add the receiving account. WeChat account is completed after the setup, after that when the system appears alarm information, you can use WeChat to inform the user in time. The WeChat alarm notification for a high noise alarm, for example, is shown in Figure 4.

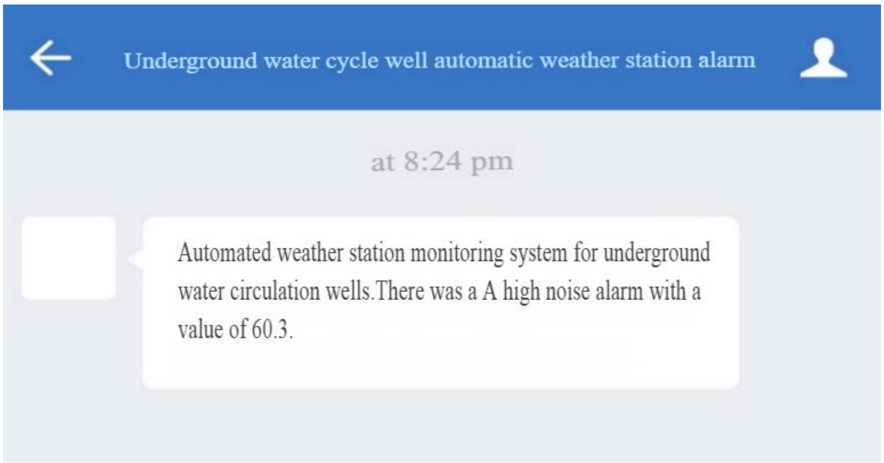


Figure 4. WeChat alarm notification.

4.4. Photovoltaic Panel Control Scheme Design

The control program for the lifting and lowering of the photovoltaic panels consists of two parts. One of them is the ModBus-TCP server communication program written by STEP 7-MicroWIN software that always runs in the PLC. This program sets the PLC to ModBus-TCP server mode through the configuration registers, and realises the one-by-one mapping between the ModBus protocol address and the internal soft components of the PLC, allowing the embedded Web server to directly monitor the inputs and outputs of the PLC using reading and writing variables, and then monitor the working status of all kinds of devices mounted on the PLC.

The second is the PV panel lifting and lowering control program written in JavaScript script that runs in the embedded Web server in a loop. The program determines the value written to the lifting variable of the power generation panel according to the magnitude of light intensity after data processing in automatic mode or the state modified by the user in manual mode, and controls the starting and stopping of the lifting motor through ModBus-TCP via PLC, to make the maximum use of light energy and guarantee the reliability of the system's energy supply. At the same time, the program also has the function of lift interlock protection.

4.5. Human-Computer Interface Design

According to the main service functions and requirements of the system, the CNWSCADA (network version) development environment software is used to design and draw the monitoring interface at the screen end, which includes two interfaces as shown in **Figure 5**: 1) system home page, 2) site monitoring interface.

System Home Page (**Figure 5(a)**):

1) Overview Panel: The home page offers a comprehensive overview of the current environmental conditions. It displays key parameters such as temperature, humidity, CO2 concentration, light intensity, atmospheric pressure, and noise levels, each represented with visually intuitive gauges and numerical values. This allows users to quickly assess the state of the monitored environment.

2) Location and Weather Information: The interface also provides a map showing the geographical location of the monitoring station, complete with coordinates, altitude, and local weather conditions (e.g., current temperature and forecast). This integration ensures that users can relate environmental data to the specific location and weather context.

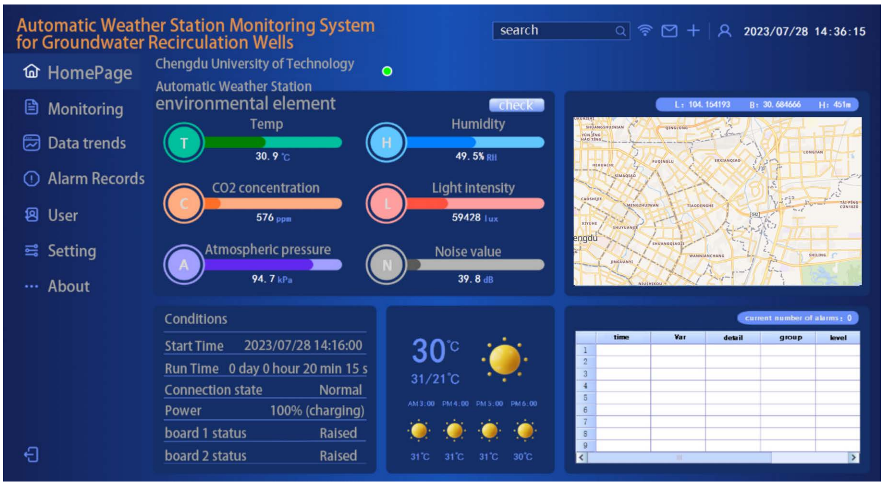
3) System Status and Alerts: At the bottom, system conditions such as run time, connection status, and power levels are displayed. This section also tracks the operational status of different boards and raises alerts if any issues arise, ensuring that users are immediately informed of any abnormalities.

Site Monitoring Interface (**Figure 5(b)**):

1) Detailed Environmental Monitoring: This interface provides a more detailed view of the environmental elements. Each parameter is listed with its current status, value, historical data, and any warning statuses. This allows users to monitor trends over time, identify potential issues, and adjust settings if needed.

2) Comprehensive System Status: The lower portion of this screen details the operational status of the system, including power, network status, and board condition. It also provides monitoring of voltage, amperage, active power and frequency. This information is critical to ensure continued system operation and to diagnose any potential power-related problems.

3) Settings and customisation: Allows users to customise parameters, set alarm thresholds and configure the display of historical data.



(a) System homepage

(b) Site Monitoring Interface

Figure 5. The main HMI of the system.

5. Results and Discussion

To verify the performance of this real-time monitoring system, it was tested for short-term data fluctuations and long-term data matching.

The test results of short-term data fluctuations are shown in Figure 6, which shows the trend curves of each environmental data collected and processed every 1 s in 20 minutes from 14:15 to 14:35 p.m. in a day, and it can be seen from the environmental data of temperature, humidity, carbon dioxide concentration, light intensity, atmospheric pressure, and noise value that the changes of all the environmental elements in the short-term are within the valid range.

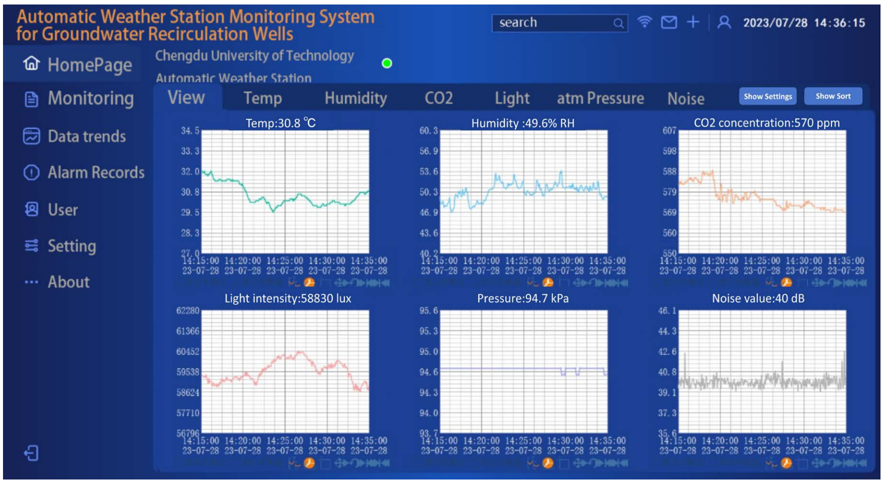


Figure 6. Test results of short-term data fluctuations.

The test results of the long-term data matching situation are exemplified by the temperature trend curve shown in **Figure 7**, which shows the trend curve plotted by temperature data collected and processed at 1s intervals from 10:20 a.m. to 2:00 p.m. in a day. It is verified that all the data constituting the temperature trend are within the valid range, which is in line with the actual temperature fluctuations.

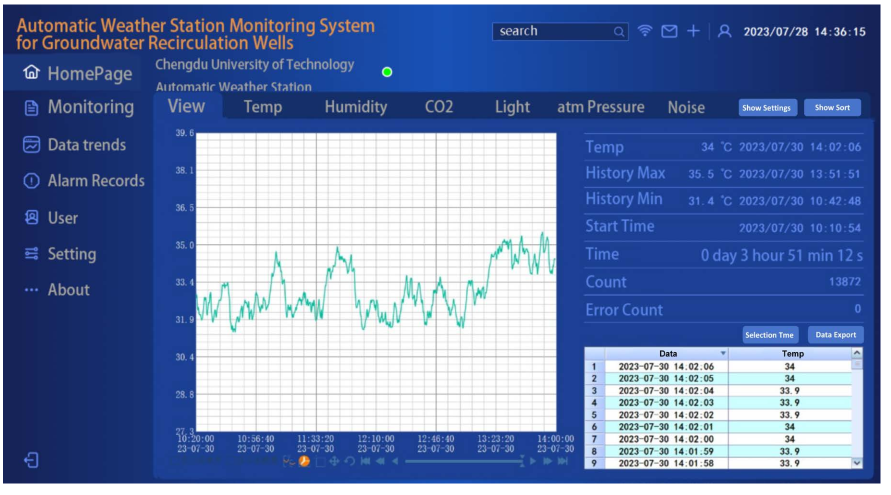


Figure 7. Test results of long-term temperature data changes.

The above tests have shown that the real-time monitoring system can monitor the environmental information of the region well under normal operation.

In the automatic mode, when the ambient light intensity exceeds the set range, the photovoltaic power generation board is automatically raised under the control of PLC. At the same time, it can also be switched to manual mode as needed, and the specified button can be pressed in the human-computer interaction interface, and the photovoltaic power generation board can also be lifted normally.

Figure 8 shows a groundwater circulation well processing site located in Hefei, China. The weather station is installed on the top of the GCW centralized control box on the right side of the figure, and the solar photovoltaic panel is also installed on the top to power the weather station and other equipment.

Figure 8. GCW processing site located in Hefei, China.

6. Conclusion

Meteorological observation plays a crucial role in groundwater remediation technology and the development of portable groundwater cycling well monitoring systems. This study presented a design for a real-time monitoring system that integrates IoT technology with supporting meteorological stations. Key achievements include the successful implementation of a self-organizing network, real-time monitoring, and remote management capabilities. The system enhances data authenticity, reliability, and manageability, providing valuable environmental data for groundwater remediation. The human-computer interface simplifies operator control and supports system maintenance and upgrades. Additionally, the use of STEP 7-MicroWIN software for PLC programming ensures efficient operation and equipment safety, reducing overall system costs. Field tests confirm the system's ability to reliably monitor environmental conditions and equipment status, ensuring efficient data transmission and system management.

Fund Project

National Key R&D Program, Integrated Equipment for *In-Situ* Synchronized Groundwater Remediation.

Project Approval Number

2020YFC1808300.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Gong, G. C., Ma, Q. M., Huang, Q. J., Sun, Y., & Yuan, S. B. (2014). A New Intelligent Weather Station Design Based on Zig Bee. *Sensors and Microsystems, No. 10,* 87-90.

Hang, H. Y., Zhang, J. Y., & Xu, W. (2017). Technological Development and Prospects of Ground-Based Automatic Weather Observation. *Journal of Electronic Measurement and Instrumentation, 31,* 1534-1542+1533. https://link.cnki.net/doi/10.13382/j.jemi.2017.10.001

Huang, F. L., Tan, H. L., & Huo, Y. (2022). Research on the Deep Integration Method of Internet of Things and Automatic Weather Station. *Computer Measurement and Control, 30,* 217-221. https://link.cnki.net/doi/10.16526/j.cnki.11-4762/tp.2022.03.036

Huang, J. Y., & Tang, H. (2020). Design of Automatic Weather Station Based on AliCloud IoT Platform. *Hubei Agricultural Science, 59,* 166-169. https://link.cnki.net/doi/10.14088/j.cnki.issn0439-8114.2020.17.038

Lv, Y. (2016). *Research on the Impact of Environmental Pollutants on the Reliability of Electrical Contact and Electronic Equipment Protection*. Beijing University of Posts and Telecommunications.

Ma, J. F., & Yan, J. Y. (2019). Exploring the Current Situation of Groundwater Pollution and the Research Progress of Control Technology. *Environment and Development, 31,* 77-78. https://link.cnki.net/doi/10.16647/j.cnki.cn15-1369/X.2019.05.045

Ma, S. F., Ma, S. C., & Liu, J. (2016). A Novel Remote Data Acquisition System for Meteorological Stations Based on the Internet of Things. *Meteorology Hydrology Marine Instrumentation, 33,* 79-82. https://link.cnki.net/doi/10.19441/j.cnki.issn1006-009x.2016.03.016

Song, G., Yue, H. K., Li, H. C., & Zhong, G. L. (2022). Advances in Groundwater Recycling Well Technology. *Groundwater, 44,* 9-13+108. https://link.cnki.net/doi/10.19807/j.cnki.DXS.2022-01-003

Xu, L. J., Sun, J. S., Li, Y. M., Zhang, B., & Zuo, D. D. (2020). Research Progress and Application Analysis of Groundwater Circulation Well Technology. *China Resource Comprehensive Utilization, 38,* 83-85.

Yin, X. J. (2018). Characterization of Groundwater Pollution and Its Application of Remediation Technology. *Groundwater, No. 1,* 73-75+118.