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"Chlorine within reach" - IoT-based hypochlorite disinfection and epidemic prevention system

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Abstract

Hypochlorous acid (HClO) solution is a food additive grade broad-spectrum disinfectant that can be used to disinfect new coronaviruses. Our project addresses the problems of unstable nature of HClO, high storage and packaging costs, and designs an intelligent HClO extermination and epidemic prevention system based on the Internet of Things. Firstly, the HClO generator is developed based on a 32 microcontroller with a touch screen and DTU to visualise and remotely monitor the HClO production process; secondly, the HClO fogging and spraying system is developed to realise environmental sensing and extermination control at the extermination site; finally, the HClO IoT platform is developed to realise remote monitoring of equipment health, environmental status based on big data analysis cloud-based visualisation The HClO IoT platform is developed to achieve remote monitoring of equipment health and environmental status and evaluation of the extermination effect based on big data analysis and cloud visualisation.

Keywords

Hypochlorous acid,disinfection and epidemic prevention system,32 microcontroller, remote monitoring, internet of things platform.

1. Hypochlorous acid

Chlorinated disinfectants are one of the more common types of disinfectants. Hypochlorous acid (HClO) is a weakly acidic and strong oxidising agent that reacts with many biological molecules such as nucleic acids and proteins, destroying their structure and causing the death of microorganisms, thus achieving disinfection [1]. Weakly acidic HClO disinfectants are characterised by low irritating odour, excellent disinfection performance and low effective chlorine concentration [2-3]. In recent years, weakly acidic HClO disinfectants have been gradually applied to various microbial disinfection treatments with remarkable results [4].

HClO disinfectant is one of the most widely used disinfectant solutions, with the advantages of high safety, ease of use, significant sterilization effect and strong antibacterial effect [5]. The principle of HClO sterilization is that HClO denatures the proteins of viruses and bacteria by decomposing to form new ecological oxygen, and releases chloride ions to change the osmotic pressure of viruses and bacteria, thus killing the pathogenic microorganisms.

Micro-acidic hypochlorous acid disinfectants are highly oxidising, broad-spectrum bactericidal and have a relatively neutral acidic pH that kills a wide range of micro-organisms including bacterial propagules, viruses, fungi and bacteriophages. When the pH of slightly acidic hypochlorous acid is stable between 5.0 and 5.8. Hypochlorous acid produces chloride ions that significantly alter the osmotic pressure of bacteria and viroids, causing their cells to become inactive and die.

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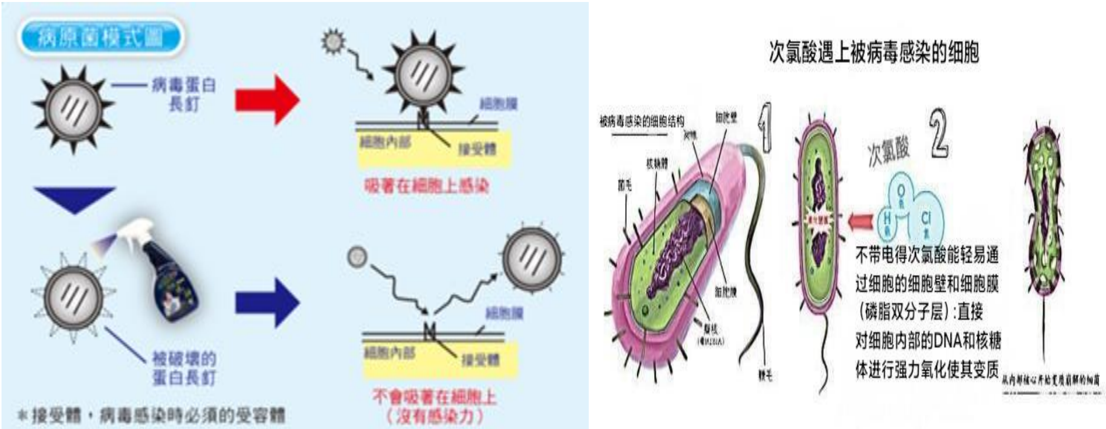
Internally, hypochlorous acid molecules are small inorganic molecules that penetrate into the cells of bacteria (viruses) and other microorganisms and react with their amino acid and enzyme systems in an oxidative manner, thereby controlling the synthesis of microbial proteins and terminating their metabolic functions before reducing themselves to water. [R-NH-R + HClO → R2NCl + H2O]

Externally: the slightly acidic hypochlorous acid forms neo-oxygen [O] after decomposition, causing the long protein pegs and outer envelope on the bacterium and virus to degenerate and fall off, rendering them non-infectious and unable to retransmit germs. This is the cause of death of the pathogenic microorganism. [HClO → H^+ + ClO^-].



The raw materials needed to prepare HClO disinfection solutions are cheap and easy to obtain, and can be prepared temporarily when HClO disinfection solutions are needed, and HClO disinfection solutions have achieved significant sterilization results in various fields [7]. As the material standard of living of the population increases, people have higher and higher requirements for food and environmental safety. Weakly acidic HClO disinfectants do not cause irritation to the gastrointestinal tract, mouth and skin due to their weak corrosive properties and good safety. After spray disinfection with weakly acidic HClO disinfectant, there is no residual disinfectant on the surface of the object. In addition, weakly acidic HClO disinfectant can control the activity and number of microorganisms in the environment and is considered an effective germicidal ingredient in food additives, so it is safe to use weakly acidic HClO disinfectant if it meets the standards. The pH value and effective chlorine concentration of HClO disinfectants are low, which reduces the contamination and irritation of disinfectants to a certain extent and has a broad application potential.

2. Extermination and epidemic prevention system

Firstly, the hypochlorite generator is developed based on a microcontroller, and a touch screen and DTU remote communication device are used to visualise and remotely monitor the hypochlorite production process; secondly, the hypochlorite atomisation spray control system is developed to realise environmental sensing and intelligent extermination control at the extermination site; finally, the hypochlorite IoT platform is developed to realise remote monitoring of equipment health, environmental status and assessment of extermination effects based on big data analysis and cloud visualisation as shown in Figure 1.

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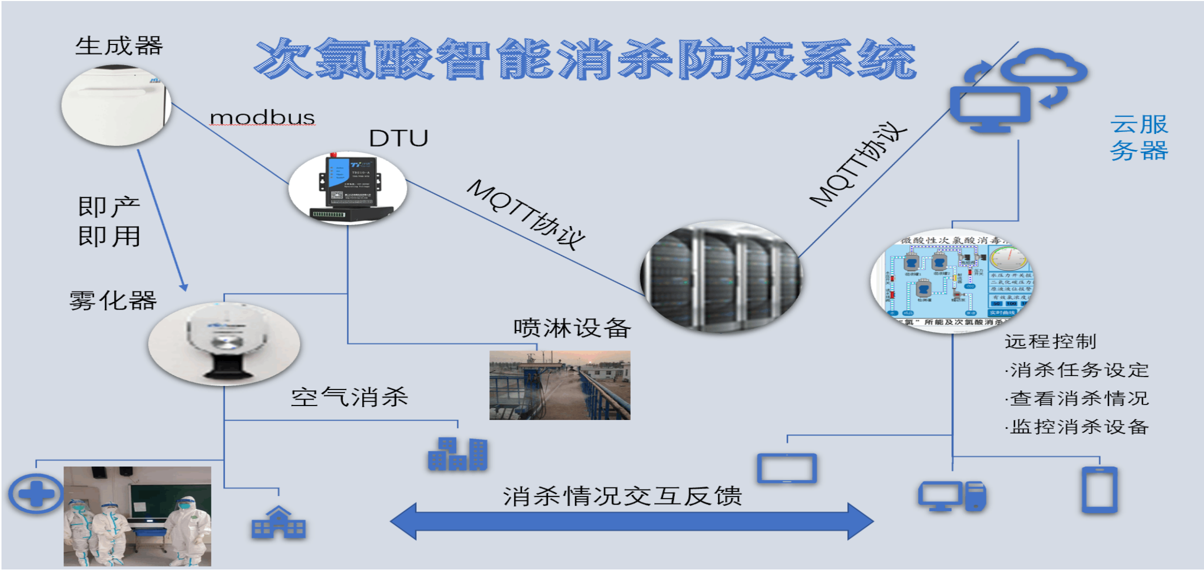

Fig. 1 Overall structure diagram

2.1. Generators

2.1.1. Technical routes

The micro-acid hypochlorite disinfectant generator control system is based on a microcontroller and its extension modules as the core, with the V-Control IoT touch screen as the human-computer interaction medium to achieve automatic control of the equipment. The system is based on the operation of the corresponding buttons on the touch screen to trigger the corresponding control program, thus outputting control signals to operate the equipment start and stop. During the operation of the equipment, a specific concentration and pH of micro-acidic hypochlorite solution can be produced continuously, and analogue quantities such as concentration, flow and pressure can be collected as feedback to achieve real-time monitoring of the equipment's working status and to ensure that the equipment achieves good disinfection results. In addition, the system has a corresponding alarm device to ensure the safe working of the machine. The functional structure is shown in Figure 2 and the control interface is shown in Figure 3:

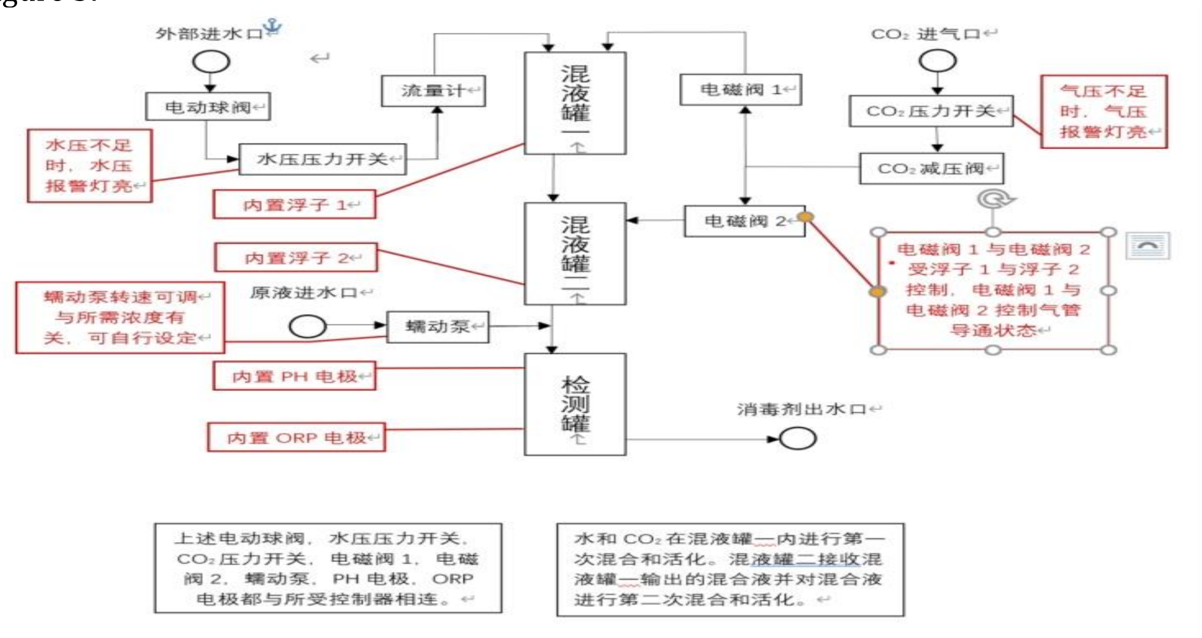

Figure.2 Functional structure of the generator

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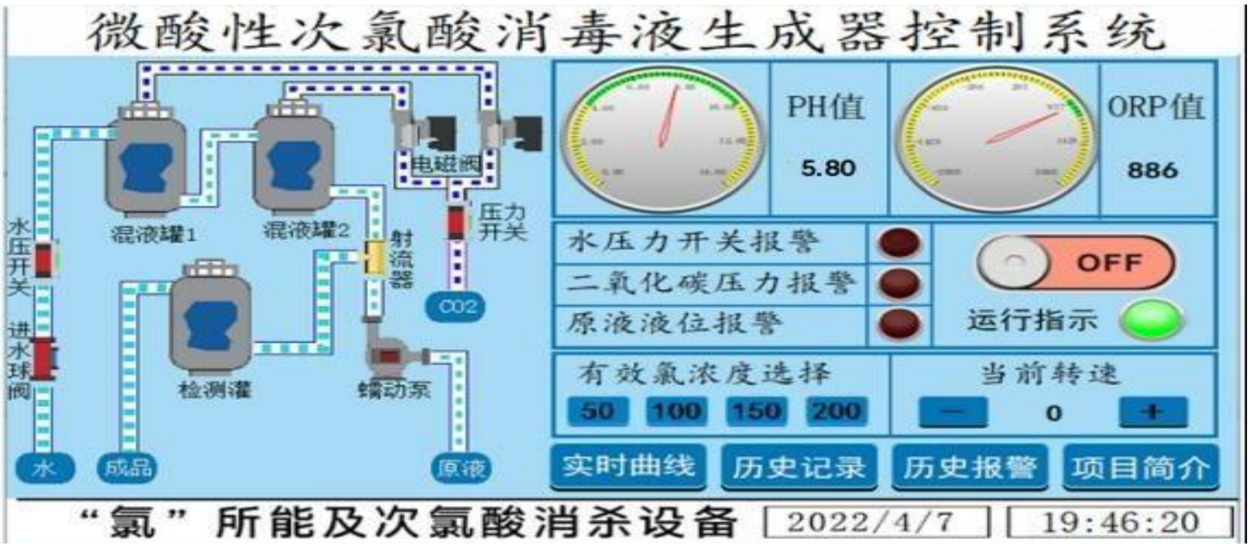

Figure.3 Generator remote control interface

2.1.2. Source code for 32 microcontroller design (partial)

```
 * Auto generated Run-Time-Environment Component Configuration File
 *      *** Do not modify ! ***
 * Project: 'BH-F429'
 * Target:  '°´¼ü'
#ifndef RTE_COMPONENTS_H
#define RTE_COMPONENTS_H
#endif /* RTE_COMPONENTS_H */

<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<ProjectGui xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="project_guix.xsd">
  <SchemaVersion>-5.1</SchemaVersion>
  <Header>### uVision Project, (C) Keil Software</Header>
  <ViewPool/>
  <SECTreeCtrl>
    <View>
      <WinId>38003</WinId>
      <ViewName>Registers</ViewName>
      <TableColWidths>115 115</TableColWidths>
    </View>
    <View>
      <WinId>346</WinId>
      <ViewName>Code Coverage</ViewName>
      <TableColWidths>1010 160</TableColWidths>
    </View>
    <View>
      <WinId>204</WinId>
      <ViewName>Performance Analyzer</ViewName>
      <TableColWidths>1170</TableColWidths>
```

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```
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 </SECTreeCtrl>
 <TreeListPane>
  <View>
   <WinId>1506</WinId>
   <ViewName>Symbols</ViewName>
   <UserString></UserString>
   <TableColWidths>80 80 80</TableColWidths>
  </View>
  <View>
   <WinId>1936</WinId>
   <ViewName>Watch 1</ViewName>
   <UserString></UserString>
   <TableColWidths>80 80 80</TableColWidths>
  </View>
  <View>
   <WinId>1937</WinId>
   <ViewName>Watch 2</ViewName>
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  <View>
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   <ViewName>Call Stack + Locals</ViewName>
   <UserString></UserString>
   <TableColWidths>80 80 80</TableColWidths>
  </View>
  <View>
   <WinId>2506</WinId>
   <ViewName>Trace Data</ViewName>
   <UserString></UserString>
   <TableColWidths>75 135 130 95 70 230 200 150</TableColWidths>
```


2.1.3. DTU

Industrial Internet of Things (IoT) is more often formed by a large number of devices with serial communication functions through DTU devices configured in STA mode and a network server, which transmits the data collected by the devices directly to the cloud and completes the data parsing in the cloud service platform [7]. As the "neuron" of the IoT sensing layer - wireless sensor network, many scholars have carried out research on multi-objective optimization, virtualization and interconnection, and the research results have solved the data link problem of the sensing layer The research results have solved the data link problem in the sensing layer. The research results have solved the data link problem at the sensing layer, optimised the query and response mechanism at the network layer, and increased the setting of publish and subscribe permissions. For data transmission, the Modbus protocol is widely used in industry [8].

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(1) IoT architecture model

A generic IoT connection topology is shown in Figure 4.

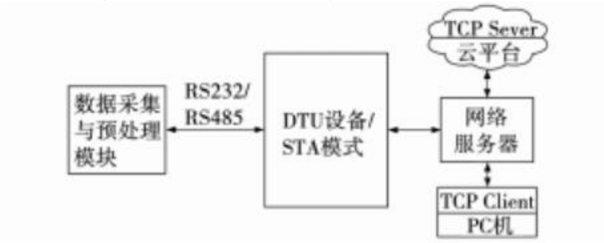

Figure.4 IoT connectivity topology

As can be seen in Figure 1, the interface standard for serial data transmission is usually RS232/RS485 and the transmission protocol is the industry standard Modbus protocol. After the data acquisition and pre-processing module has collected the device data, it generates the required parameter information through calculation and the DTU device transmits this information to the cloud according to the Modbus protocol. This paper focuses on the Mod-bus message transmission mode between the DTU device and the data acquisition and pre-processing module.

(2) Time division multiplexing

The digital signals transmitted by the network are derived directly or indirectly from the sensor, which converts the sensed analogue quantities into digital quantities by satisfying Nyquist's sampling theorem: fs ≥ 2fh. The interpolation formula for recovering the analogue signal from the sampled signal is xa (t) = xa (nT) Sa [π(t - nT) /T].

n = -!

The digital signal can represent the original analogue signal without distortion as long as the sampling theorem is satisfied during the analogue-to-digital conversion, but the digital signal is then the baseband signal . In order to maximise the use of the channel and reduce transmission costs, the baseband signal is often multiplexed before transmission. Time division multiplexing (TDM) is a common modulation method in which different time domain signals are intertwined in different time slots and transmitted along the same physical channel, and the signals in each time slot are then extracted and restored to the original signal by some method at the receiving end. It is a communication technique in which different time slots are interwoven and transmitted along the same physical channel. The principle of operation is shown in Figure 5.

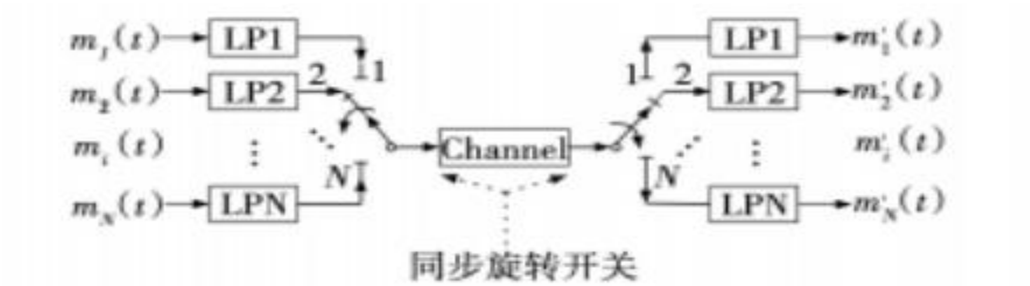

Figure.5 Time division multiplexing principle

As can be seen in Figure 2, there is a mechanical rotary switch at the transmit and receive ends that rotates synchronously at the sampling frequency. At the transmitter side, this switch samples the input signals in turn, and the sampled values of the multiple signals obtained by rotating the switch for one week are combined into one frame. The switches rotate periodically, polling each signal in turn, and each signal is sent intermittently in turn [9], with each signal sharing the same physical channel when transmitted. Time division multiplexing facilitates digital communication, is easy to manufacture, greatly improves channel utilisation, and saves hardware costs while ensuring communication quality.

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(3) Modbus-RTU protocol

When the controller is set to communicate in RTU (Remote Terminal Unit) mode on a Modbus network, the message frame is used to read the values of multiple registers, for example, the format of the host query message is: device address, function code, high and low bits of the start register, high and low bits of the number of registers are 1 byte, check CRC16 is 2 bytes. Address, function code and return data byte are 1 byte, return data N byte, and check bit CRC16 is 2 byte. The "number of returned data bytes" in the slave response message format is twice as many as the "number of registers" in the host query message format, and the "number of returned data bytes" in the slave response message format is only one byte. The number of data bytes returned" in the slave response message format is only one byte, so theoretically only a maximum of 255 registers can be obtained in one query. In some specific industrial applications where a large number of attributes are generated by edge computing, or where the range of register addresses in which the parameters are stored is not continuous, the following method can be used to upload all parameters together in order to ensure real-time monitoring.

2.2. Modbus slave queries

Provided that Nyquist's sampling theorem is satisfied and that the processor can process the data throughput in a timely manner, a query cycle can be split into a number of time slots, each of which then processes a timing signal all the way through. An illustration of the time slot split is shown in Figure6.

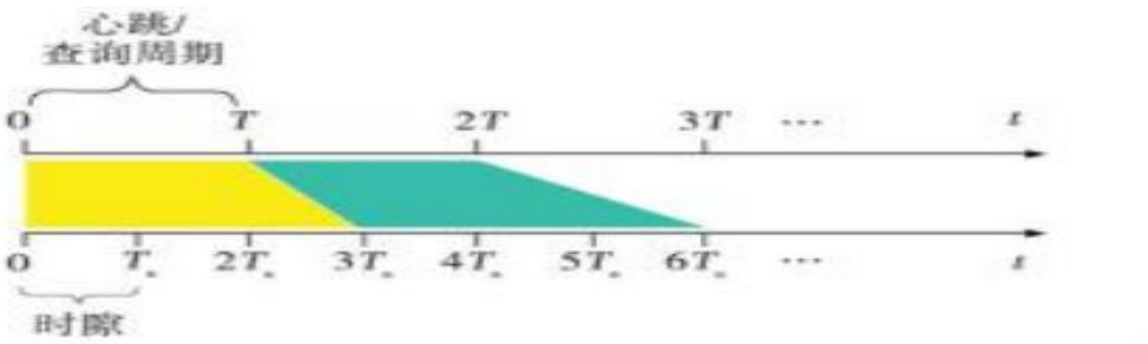

Figure.6 Illustration of time slot splitting

In Figure 3, a query cycle is split into 3 time slots. For real-time monitoring of power quality parameters in this text, a refresh rate of seconds is sufficient. Therefore, a baud rate of 9 600 is quite sufficient for serial communication. If one heartbeat (query cycle) requires N commands to read back all parameters, the overall query command satisfies the following relationship

$$I(t) = \sum_{i=0}^{N-1} C_i R_{T_s}(t - iT_s) , \quad (3)$$

$$R_{T_s}(t) = \begin{cases} 1, & 0<t<T_s, \\ 0 & \text{其他}, \end{cases} \quad (4)$$

Since the "device address" and "function code" in the slave response are the same for all time slot commands, the "number of registers" must be set differently for each time slot query command to facilitate correct parsing of the returned data.

2.3. Nebulisers

The matching fogging extermination equipment can achieve the collection of parameters such as temperature, humidity and PM2.5 of the site environment, according to the user's extermination plan, to achieve human-machine coexistence, air extermination, sensing the environment, positioning monitoring, 24 hours a day, anytime, anywhere, with the amount of air gas extermination. The control flow of the fogging and extermination equipment is shown

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in Figure 7, the fogging flow diagram is shown in Figure 8 and the current circuit diagram based on the microcontroller design is shown in Figure 9:

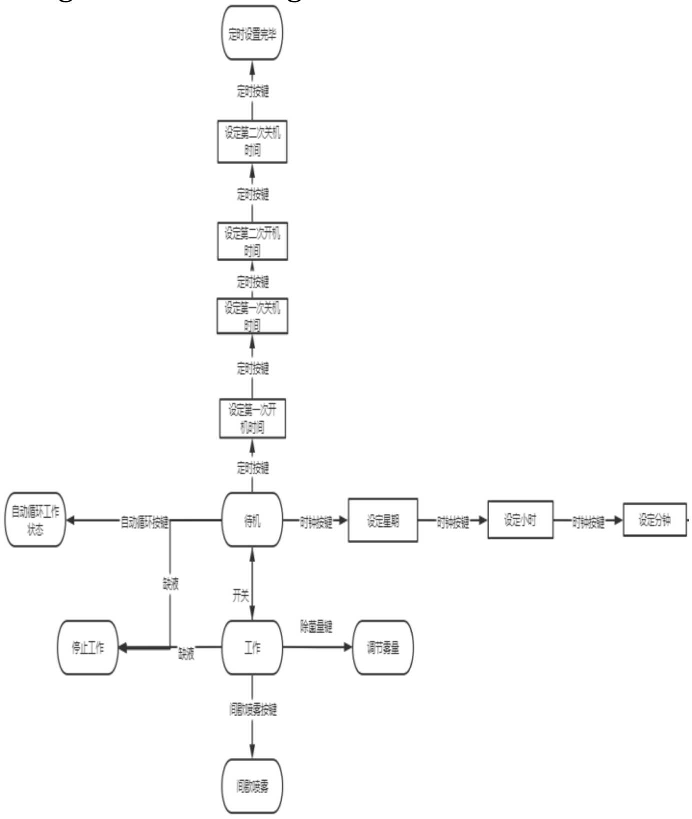

Fig. 7 Control flow diagram of the fogging and disinfection equipment

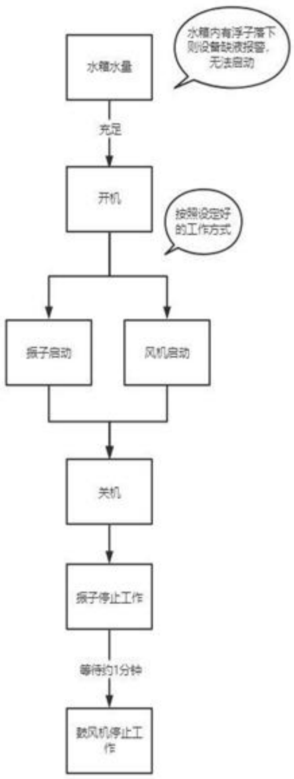

Fig.8 Flow chart of atomisation

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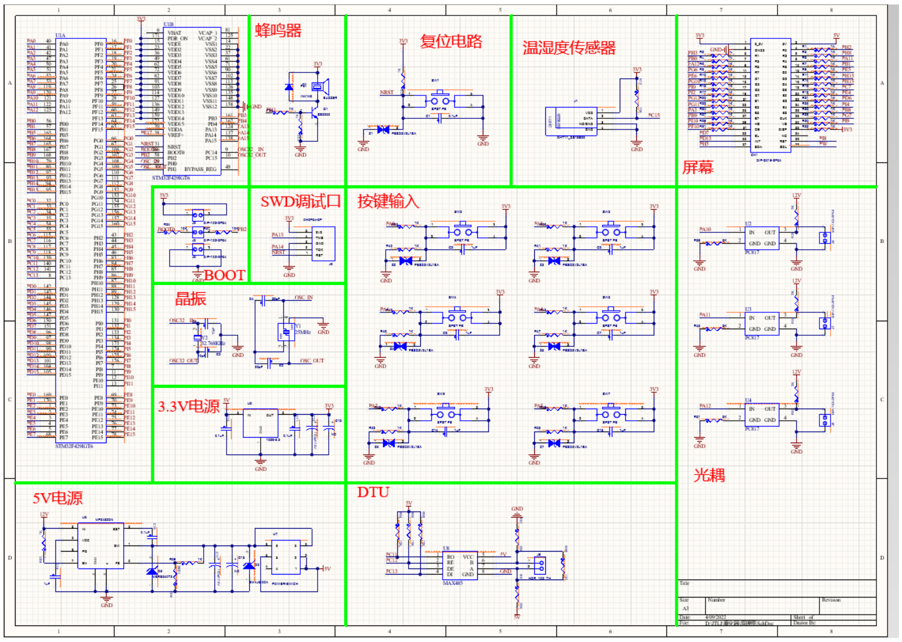

Fig. 9 Circuit diagram of the fogging and disinfection equipment

2.4. IoT platform

2.4.1. Technical routes

The client side of the "chlorine can and" network intelligent hypochlorous acid extermination equipment management system adopts a B/S structure, the system development adopts the technology of front and back-end separation, using node.js for background code writing. The front-end interface is designed using the vue2 framework, using the axios library to achieve front and back-end interaction. Users can access the system directly through a computer browser without having to download a client, which is characterised by fast access, low equipment requirements, strong management capabilities and timely information synchronisation. The management system can add new equipment at any time, monitor equipment in a timely manner, and also manage project, product and user information, realise real-time presentation of equipment status throughout the process, maintenance-free design in the cloud, comprehensive presentation of the extermination status and statistics of the facilities in the managed environment, visualisation of big data analysis in the cloud and big data analysis of the extermination environment and assessment of the extermination effect management. Its functional structure diagram is shown in Figure 10. The management system currently developed is available at http://39.106.0.22:3000/ and part of the interface is shown in Figure 11 and Figure 12:

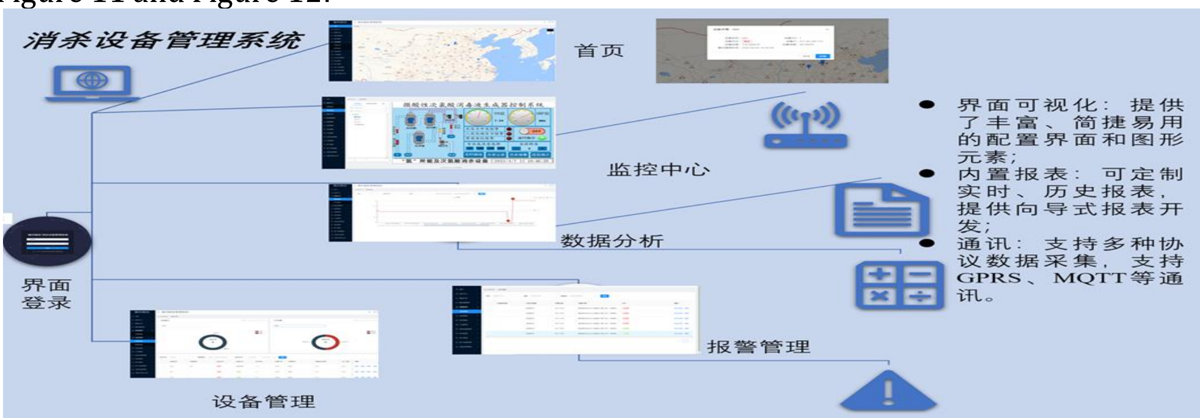

Figure.10 Functional structure of the IoT platform system

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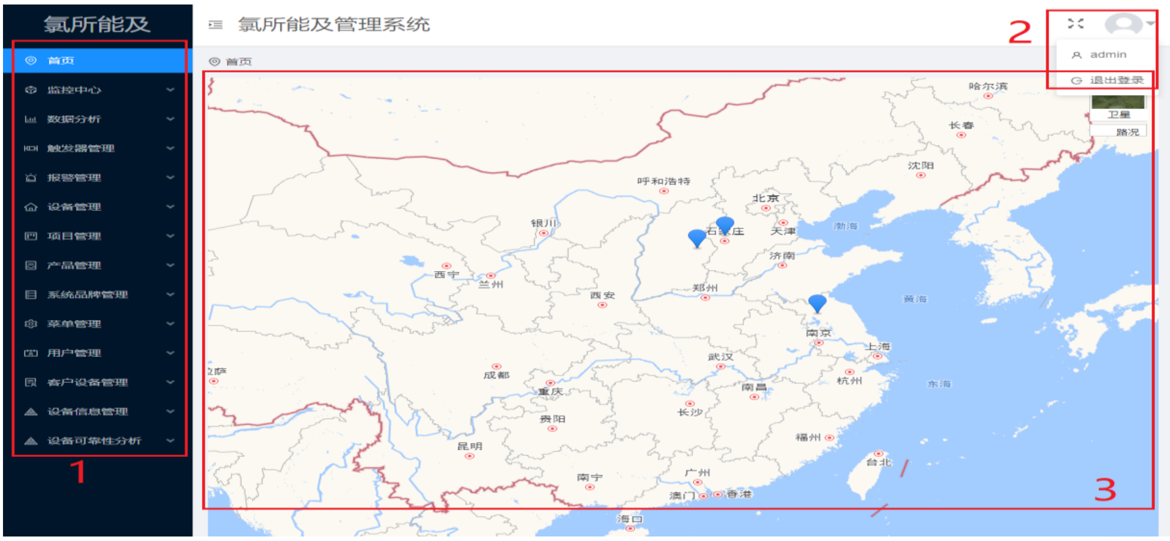

Fig. 11 Device location and management interface

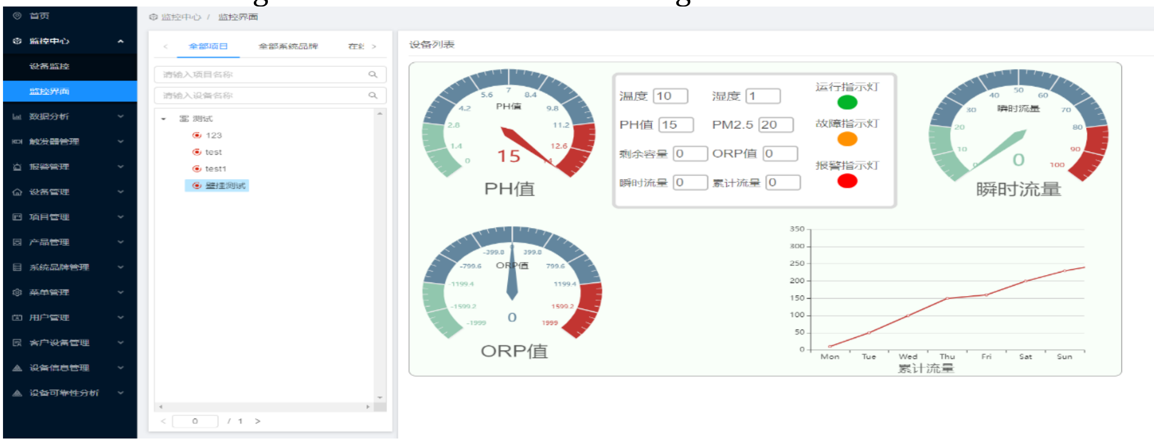

Fig. 12 Remote control interface of the generator

2.4.2. Design Source Code (Partial)

```
/* floading ? (<div className="spinLoading"><Spin> </Spin></div>)
 : null} */}
<Row gutter=[[8， 16]}>
<Col span={5}><ProjectAndDeviceSelect onTreeSelect={this.onTreeSelect] />
</Co1>[/* <Col span=(19) style=ll display: 'none' }> */)
<Col span={19}>
<Spin tip="获取设备中...” spinning={loading}><div className="shadow-radius"
<p>设备列表</p>
<Divider style=ff marginTop: 10,marginBottom: 10 11 />
(/* <FilterForm searchEnter=fthis. searchEnter.bindthis) 》 params=fthis.state,params
setParams=fthis. setParams.bin<div className=['${style.main}'}>
<ul className=[}>...
const mapStateToProps = state => state;const mapDispatchToProps = dispatch => (fsetUserInfo:
data => !dispatch(setUserInfo(data)):
export default connect(mapstateToPropsmapDispatchToProps)(withRouter(MonitorList))
pageNo ?
//加载表格数据Loading
showTableLoading = () => [//console.Log('开启Loadding');
```

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```
this.setState({ loading: true });
closeTableLoading = () => [//console.Log('关闭Loadding');
this.setstate({ loading: false ]);
//头部状态过滤
filterLoadData(status) {
this.setState({
params: f ...this.state.params, status, pageNo: 1 1
1);
//当父组件有删除等换作，须享到参数重新请求列表，这里获取参敬setParams(params) [
this.setState({ params ]);
// 博索过滤
searchEnter(f data,total }) {
this.setState(!
data: data,
total,
```

3. Innovative features

The equipment is mainly designed to solve the problems of unstable hypochlorite disinfection solution, high cost and low scientific nature of disinfection management. The generator developed in this project is ready to use, and only needs to be connected to a water source to add sodium hypochlorite mother liquor to run. The cost of producing one tonne of disinfection solution is no more than 300 RMB, but its current market price is around 50,000 RMB, and its economic benefits are obvious.

The intelligent fogger designed for this project can be used to disinfect air gases at any time, anywhere and in any amount, and can be used to carry out intelligent automatic disinfection treatment based on environmental monitoring. The project is suitable for a variety of scenarios with dense crowds and sealed premises, replacing the high-risk operations of cleaning staff at the site of an epidemic, reducing the risk of cross-infection among frontline staff, protecting the health and safety of frontline staff, and effectively improving disinfection efficiency and safety.

The intelligent IoT management platform developed enables real-time presentation of the entire operation and maintenance status of equipment, intelligent operation management in the cloud, analysis of the disinfection status of facilities and statistical data of the managed environment, visualisation of big data analysis in the cloud as well as big data analysis of the disinfection environment and assessment management of disinfection effects.

4. Conclusion

The system is designed and developed to address the shortcomings of hypochlorite and includes a 32 microcontroller based hypochlorite generator and an atomiser that can be detected and controlled by the IoT in real time, connected to a DTU developed independently via modbus remote protocol and uploaded to the IoT. The self-developed IOT management system can add new equipment at any time and monitor the equipment in a timely manner, while also managing the project, product and user information, realising real-time presentation of equipment status throughout, maintenance-free design in the cloud, comprehensive presentation of facility disinfection status and statistical data of the managed environment, realising big data analysis in the cloud visualisation as well as big data analysis of the disinfection environment and disinfection effect assessment management.

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