Dynamic Control System of Automatic Monitoring Equipment for Waste Gas Pollution Source

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Abstract In order to improve the quality of automatic monitoring data of pollution sources and apply the automatic monitoring data to verify the environmental tax, Shandong Province took the lead in adopting the Internet of Things technology and drawing on the successful experience of air automatic monitoring stations and surface water automatic monitoring stations in management, and developed a dynamic management and control system for automatic monitoring equipment of pollution sources to improve and strengthen the quality audit of automatic monitoring data, further improve the quality of automatic monitoring data and better provide a basis for environmental management and decision making. The system realizes the simultaneous monitoring of monitoring data, running state and parameters of the automatic monitoring equipment, eliminates the phenomenon of falsification by modifying equipment parameters, and judges the validity of the collected data by acquiring the working state of the equipment remotely and randomly. After the actual operation test of the Department of Ecological Environment of Shandong Province, the system is proved to have the characteristics of practicality, real time and high efficiency, and be able to make up for low frequency and narrow coverage of manual inspection, with good application prospect in the field of environment and pollution source monitoring.

Key words Dynamic management and control, Monitoring data, Running state, Equipment parameter, Negative control

1 Introduction

The online monitoring system of pollution source emission is a powerful guarantee for promoting the construction of ecological civilization, an important part of the national ecological environment monitoring network, an important foundation for the implementation of pollution source supervision and improvement of environmental quality, and also the main way for the public to understand the environmental situation. Online monitoring data has been widely used in environmental emergency, environmental early warning, ecological assessment, administrative law enforcement, information disclosure, environmental tax collection and other aspects. Therefore, how to improve the effectiveness and accuracy of automatic monitoring data has become the focus of eco-environmental departments.

Shandong Province, as a big economic province, has a large number of pollution sources, a large amount of sewage, complex water and gas environment, and relatively scattered distribution. According to statistics, more than 80% of the main pollutants produced in Shandong Province are concentrated in more than 1 200 waste gas and wastewater enterprises and 260 urban sewage treatment plants. To manage these enterprises and sewage treatment plants well means to control the discharge valves of the whole province. At present, the monitoring of key pollutant discharge units in Shandong Province is only data monitoring. The actual operation and maintenance of on-site monitoring equipment can not be mastered, and the audit basis is relatively single. In addition, some pollutant discharge units and third-party operators interfere with the operation of monitoring equipment driven by economic interests. As a result, part of the monitoring data and monitoring information can not objectively and accurately reflect the actual pollution situation. Although the local ecological and environmental bureaus have stepped up their investigation and punishment efforts, manual inspection and comparison can't solve the problem fundamentally due to heavy workload and low efficiency.

In order to improve the quality of automatic monitoring data and use automatic monitoring data of pollution sources to verify environmental tax, Shandong Province took the lead in adopting Internet of Things technology and learning from the successful experience of air automatic monitoring stations and surface water automatic monitoring stations in management, established a dynamic management and control system for automatic monitoring equipment of pollution sources to improve and strengthen the quality audit of automatic monitoring data, further improve the quality of automatic monitoring data, lay the foundation for environmental tax collection, and provide a better basis for environmental management and decision-making.

By transforming the on-site automatic monitoring equipment and data acquisition and transmission instrument, the system realizes the simultaneous monitoring of monitoring data, running status and parameters of automatic monitoring equipment, eliminates the phenomenon of falsification by modifying equipment parameters, and judges the validity of collected data by acquiring the working state of the monitoring equipment remotely and randomly. The system has passed the actual operation test of the Department of Ecological Environment of Shandong Province and is proved to be practical, real-time and efficient, and be able to make up for the

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low frequency and narrow coverage of manual inspection, with good application prospect in the field of environmental monitoring.

2 Current situation of on-line monitoring system of pollution sources and concept of negative control

At present, most regions in China have realized 24-h automatic monitoring of major pollutants in key pollutant discharge units. Based on the data uploaded by the automatic monitoring platform, it could be concluded that most of the pollutant discharge units meet the discharge standards. However, this is not the case. In recent years, unexpected environmental problems have occurred from time to time. For example, air pollution all over China has brought haze into people's view. It has a great impact on people's vision and health, and has attracted the global attention[1]. Pollutant discharge units have to invest a lot of financial and material resources every day to keep up to the discharge standard. Driven by economic interests, some pollutant discharge units choose to commit fraud. As a result, some automatic monitoring data can not truly reflect the actual situation of sewage discharge. The "electronic eye" of the online automatic monitoring equipment has been turned into a device. Apparently, it is clairvoyant, but in fact, it runs in a blind way, making the monitoring personnel unable to understand the actual emission situation of enterprises.

As shown in Fig. 1, the current automatic monitoring system mainly includes automatic monitoring equipment, data acquisition and transmission system and monitoring center. The automatic monitoring equipment is composed of sampling system, analysis system and data processing system (industrial personal computer, IPC). Judging from the inspection of monitoring centers in various places, the ways of falsification are mainly concentrated in sampling pipeline and data processing system (IPC). The falsification of data processing system, *i. e.* IPC, is carried out by modifying parameters. This method is easy to operate, easy to recover but difficult to obtain evidence, accounting for the majority of cases of falsification. The second is the falsification of sampling system, such as blocking the probe inlet and changing the position of the sampling probe in the flue. This method is costly, difficult, easy to be investigated and dealt with, and is rarely found at present. According to the inspection statistics, falsification by modifying parameters accounts for about 85% of total cases of falsification, and pipeline falsification accounts for about 15%.

Fig. 2 shows a case investigated and dealt with by Shandong Provincial Eco-environment Monitoring Center. The manual monitoring data of the enterprise was 1 822 mg/m^3, exceeding the standard by 3.6 times. The data uploaded to the monitoring platform by the data acquisition instrument was 182 mg/m^3. After investigation and analysis, it is found that the personnel of the enterprise arbitrarily modified the slope (a) of the determination curve ($y = ax + b$) of SO_2 in IPC from the normal value 1 to 0.1, resulting in the uploaded monitoring data being about 1/10 of the actual data. From this example, we can see that the current environmental monitoring system only realizes the functions of collecting environmental monitoring data regularly, storing data and transmitting data remotely, but has loopholes. Falsification can be conducted through modifying the parameters of IPC.

This paper mainly studies how to prevent the modification of equipment parameters, how to upload the running status of the device to determine the validity of the monitoring data, how to realize the reverse control of environmental monitoring instrument through the network and how to set the state parameters of monitoring sub stations when the staff are not on the site, in order to realize the remote control of equipment, including blowback, calibration, returning to zero, standardization, start and stop. Reverse control is a term of monitoring industry. That is to say, under the condition of Internet or wireless communication, the authorized client in the monitoring center sends control command through web browser, which is transmitted to the embedded data acquisition and transmission instrument at the monitoring site, realizing communication through RS485/RS232 with on-site monitoring instruments [such as gas analyzers of Shimadzu (Japan), Focused Photonics (Hangzhou) and SDL (Beijing)], controls the operation of on-site instruments, and parameters and running status of uploading instrument, acquires monitoring data, uploads the data collected to the server of the monitoring center and displays dynamically the results in the browser[2].

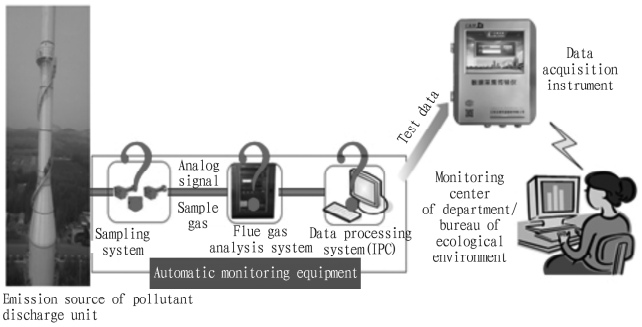


Fig. 1 Data acquisition and transmission mode of automatic monitoring system of pollution source

3 Solution: establishing a dynamic control system for automatic monitoring equipment of waste gas pollution sources

In order to effectively solve the above problems, based on the existing online monitoring system of pollution sources, the IPC is removed from the original system, the analyzer is directly connected with the data acquisition instrument, and the monitoring equipment and data acquisition instrument are reformed to make the data acquisition instrument undertake the data processing function of the original IPC (Fig. 3). At the same time, the working state and key parameters of the analyzer are collected. In this way, the monitoring data, working status and key parameters of the automatic monitoring equipment can be uploaded simultaneously. When the working state of the equipment is abnormal or the parameters change, the system will alarm automatically.

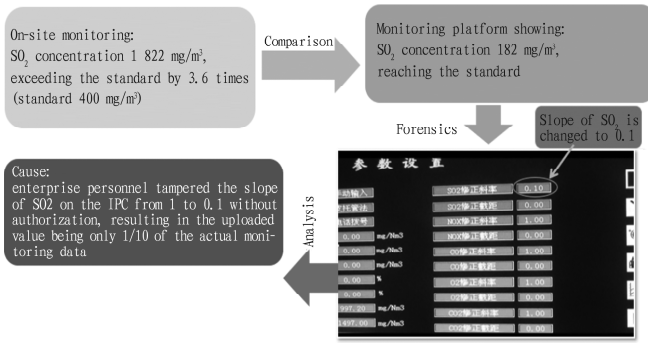


Fig. 2 An example of modifying parameters through industrial personal computer (IPC)

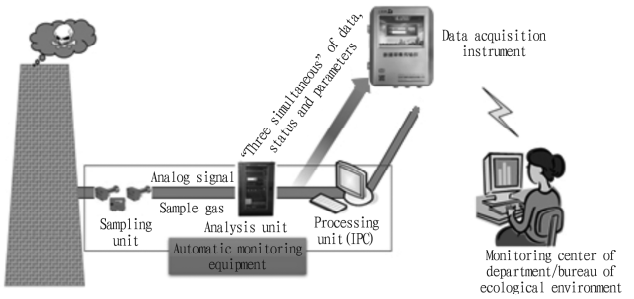


Fig. 3 Data acquisition and transmission mode of automatic pollution source monitoring system after the implementation of the project

3.1 System architecture The overall architecture of the system is shown in Fig. 4. On the monitoring site, through connecting the data acquisition instrument with the monitoring equipment, the monitoring data, equipment parameters, equipment status, alarm information and other data are obtained and uploaded to eco-environment department through wireless network. The ecological environment department receives and stores data, audits the data automatically and intelligently through the software platform, and sends reserve control commands to the monitoring equipment at the same time, including changing equipment parameters and changing equipment working state. These control commands are received by the data acquisition instrument and then transmitted to the monitoring equipment. The whole system is based on data acquisition instrument. Through the communication between data acquisition instrument and monitoring equipment, and the communication between data acquisition instrument and upper software of ecological environment department, the communication between platform end and on-site monitoring equipment is realized.

The logical architecture of the system is shown in Fig. 5.

At the bottom monitoring site, the interconnection between data acquisition instrument and monitoring equipment is realized through the transformation of communication protocol. All kinds of data collected by data acquisition instrument are encrypted and uploaded to the eco-environment department.

The encrypted data has gone through the following processes in the software platform of the eco-environment department.

(i) Through the real-time communication module, the bottom SCADA system receives the data uploaded by acquisition instrument on each monitoring point (automatic adaptation through protocol adaptation). Through the data decryption module, the uploaded data is decrypted. The decrypted data is stored in real-time memory database.

(ii) After the data is stored in the real-time database, after preliminary sorting, on the one hand, it is transferred to the relational database, and on the other hand, the real-time data is directly used by the monitoring system.

(iii) The data of relational database is automatically audited through data audit system, and the data after audit shall be stored separately.

(iv) The dynamic control system of waste gas pollution source realizes the "three simultaneous" monitoring of monitoring data, equipment parameters and equipment status, as well as equipment reverse control function. Through the real-time database, SCADA and other systems, the control command is sent to the monitoring equipment.

(v) The system provides external data interface for other systems to call.

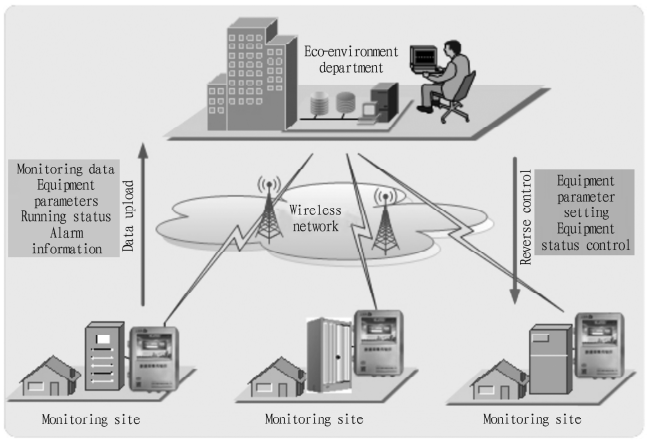


Fig. 4 System architecture

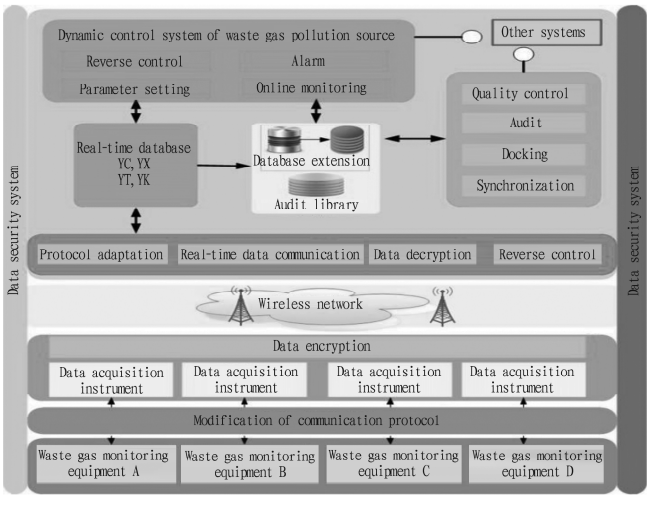


Fig. 5 System logic architecture

3.2 Composition of negative control system The reverse control system is shown in Fig. 6. The system is generally composed of two parts: control center and monitoring station. The control center needs to add a control module to the existing envi-

ronmental monitoring platform software. Each monitoring station is composed of ARM9 microprocessor embedded data acquisition and transmission instrument and on-site monitoring equipment (intelligent equipment such as flue gas analyzer). The intelligent interface board on the data acquisition and transmission instrument can effectively support the access of multiple instruments. It can be connected with RS232, RS422, RS485, digital I/O and other interfaces of monitoring instruments, realizing "wide access" of instrument interface at monitoring point and effectively supporting the functions of instruments from different manufacturers, such as sampling, cleaning, calibration and consumables inventory inspection[3].

The data acquisition instrument collects the monitoring data, operation status and parameters of the on-site equipment, and transmits to the monitoring center. The staff in the monitoring center can judge the accuracy and validity of the monitoring data according to the equipment parameters and instrument status. On the other hand, the authorized users in the monitoring center send control command through dynamic control software, and the control command is transmitted to the embedded data acquisition and transmission instrument at the monitoring site. Through communication with on-site monitoring instrument through RS485/RS232, the operation of on-site equipment is controlled.

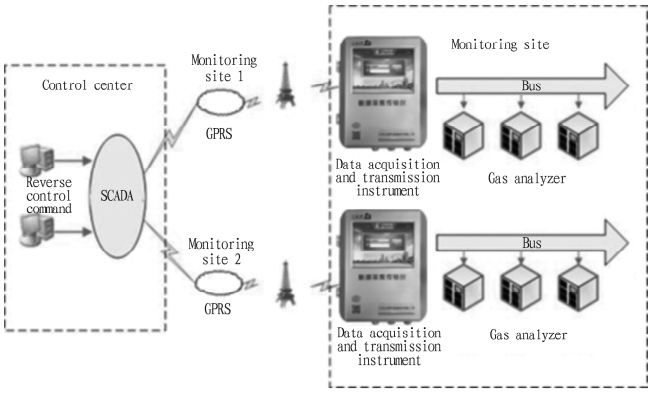


Fig. 6 Composition of reverse control system

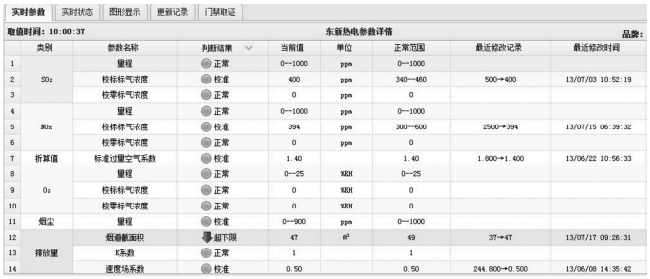
3.3 Functions of pollution source dynamic control system

The dynamic management and control system realizes the "three simultaneous" monitoring of the operation status, working parameters and monitoring data of the automatic monitoring equipment, and carries out alarm, remote reserve control and capture for the abnormal status and parameters. The main functions of the system are as follows.

3.3.1 Data monitoring. It is compatible with the original mode of Shandong environmental automatic monitoring system. The monitoring index of each station is kept. Real time data and historical data can be queried, and the measured value can be uploaded.

3.3.2 Monitoring of working parameters. Working parameters such as measuring range, curve slope, curve intercept, flue section area, pitot tube coefficient and velocity field coefficient are monitored in real time. The parameter modification log is saved automatically.

As shown in Fig. 7, the record of abnormal parameter alarm can be viewed, and the details of the parameters in the exception can be seen directly. In addition, other parameters of the equipment, as well as their respective conditions, current values, normal ranges and latest modification record can be seen.


实时参数 | 实时状态 | 图形显示 | 更新记录 | 门禁取证

取值时间：10:00:37　　东新热电参数详情　　品牌：

	类别	参数名称	判断结果	当前值	单位	正常范围	最近修改记录	最近修改时间
1		量程	正常	0--1000	ppm	0--1000		
2	SO_2	校标标气浓度	校准	400	ppm	340--460	500→400	13/07/03 10:52:19
3		校零标气浓度	正常	0	ppm	0		
4		量程	正常	0--1000	ppm	0--1000		
5	NOx	校标标气浓度	校准	394	ppm	300--600	2500→394	13/07/15 06:39:32
6		校零标气浓度	正常	0	ppm	0		
7	折算值	标准过量空气系数	校准	1.40		1.40	1.800→1.400	13/06/22 10:56:33
8		量程	正常	0--25	%RH	0--25		
9	O_2	校标标气浓度	正常	0	%RH	0		
10		校零标气浓度	正常	0	%RH	0		
11	烟尘	量程	校准	0--900	ppm	0--1000		
12		烟道截面积	超下限	47	m^2	49	37→47	13/07/17 09:26:31
13	排放量	K系数	正常	1		1		
14		速度场系数	校准	0.50		0.50	244.800→0.500	13/06/08 14:35:42

Fig. 7 Monitoring of working parameters

3.3.3 Monitoring of running status. Sampling, measurement, calibration, fault and other operation conditions of automatic monitoring equipment can be monitored in real time. The monitoring data in abnormal state are identified.

After entering the working state monitoring interface of the equipment, and the fault points and details of abnormal equipment, as well as monitoring items included in the working status of the site can be viewed directly (Fig. 8).


实时参数 | 实时状态 | 图形显示 | 更新记录 | 门禁取证

取值时间：15:40:02　　黄台电厂(8)状态详情　　品牌：日本岛津 刷新

	类别	项目名称	判断结果	当前状态	全部状态	最近变更记录	最近变更时间	历史记录
1	数采仪状态	通讯状态	正常		连接,断开			
2		与烟尘分析仪连接状态	正常	连接	连接,断开	'断开'→'连接'	13/04/20 13:33:38	查看
3		与气体分析仪连接状态	正常	连接	连接,断开	'断开'→'连接'	13/04/15 11:26:15	查看
4		工作状态	正常	正常	正常,异常	'异常'→'正常'	13/04/20 05:24:36	查看
5	CEMS设备状态	烟尘分析仪运行状态	正常		运行,停止			
6		反吹状态	正常	待机	待机,运行	'运行'→'待机'	13/03/21 20:02:16	查看
7		反吹状态	正常	待机	待机,运行	'运行'→'待机'	13/03/19 15:04:31	查看
8		校准状态	正常	待机	待机,生标,生零,校正	'校正'→'待机'	13/07/11 12:09:05	查看
9		故障状态1	正常	无故障	二氧化硫温度调节基故障,无故障,一氧化碳温度调节'二氧化硫温度调节基故障'→'	13/04/14 06:13:58	查看
10		故障状态2	异常	RS-232C PORT1故障	装置内温度基故障,无故障,手标故障,RS-232C PORT'无故障'→'RS-232C PORT1故障	13/07/17 12:03:23	查看

Fig. 8 Monitoring of running status

3.3.4 Abnormal alarm. The abnormal working parameters, operation status and parameter modification of automatic monitoring equipment are alarmed. As shown in Fig. 9, which stations are abnormal in parameter, which sites belong to equipment failure and which sites belong to normal are indicated by different colors. When there is a new alarm, there will be voice broadcast, and a prompt box will pop up to remind the personnel on duty to pay attention to it and conduct selective on-site inspection.


01 星期三　实时监控 | 单站详情 | 报警总览 | 异常报告 | 统计报表 | 操作日志 | 系统设置　国气

取值时间：21:33:44　　实时监控　　刷新

	城市	站点名称	实时状态	最近参数异常时间	最近设备状态改变时间
1	济南	北郊热电	正常	--	--
2	济南	东新热电	参数异常	2013-07-17 09:26:31	2013-07-16 13:12:30
3	济南	庚辰钢铁(烧结1)	正常	--	2013-07-15 09:46:06
4	济南	庚辰钢铁(烧结2)	校准	--	--
5	济南	华明水泥(1)	正常	--	--
6	济南	黄台电厂(10)	校准	--	2013-07-17 10:22:36
7	济南	黄台电厂(7)	校准	--	2013-07-17 11:24:13
8	济南	黄台电厂(8)	设备故障	--	2013-07-17 12:03:23
9	济南	黄台电厂(9)	校准	--	2013-07-17 10:57:49

Fig. 9 Monitoring of abnormal alarm

3.3.5 On-spot evidence collection. Through the access control system, the personnel entering the monitoring station room are photographed and taken evidence, and the forensics information is uploaded to the monitoring center. When there is a parameter

modification alarm, the remote video forensics function can be started to obtain the in-scene video information.

3.3.6 Reverse control. The on-site equipment is controlled and operated reversely, such as blowback, calibration, turning to zero, standardization, start and stop and cleaning.

3.3.7 SMS notification. When there are abnormal working parameters or running state of monitoring equipment, SMS can be sent to relevant responsible persons of operation companies or monitoring departments at all levels.

Note: The above-mentioned equipment parameters, working conditions and reverse control functions are common examples, and the details should be decided by different types of equipment on site.

3.4 Impact of equipment parameter change on monitoring indexes Fig. 10 shows the influence of flue section area on the monitoring data of waste gas emission. Red represents the cross-sectional area of flue, blue represents the emission per hour. Around 10:20, when the cross-sectional area of the flue was modified, the emission per hour decreased immediately; and around about 10:45, when the cross-sectional area is restored, the emission was restored.

Fig. 11 shows the influence of the standard gas coefficient on the concentration of SO_2. At about 15:20, the standard gas coefficient was modified, and the concentration of SO_2 became smaller after a few minutes delay.

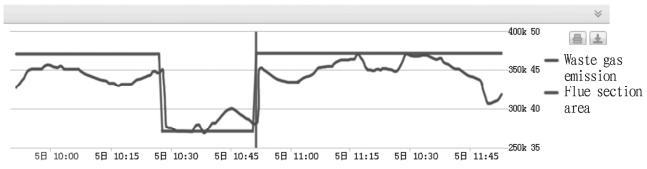


Fig. 10 Influence of flue section area on waste gas emission

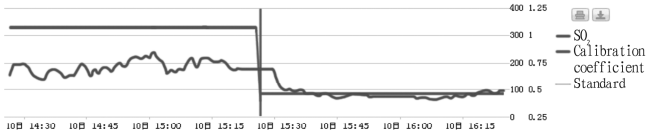


Fig. 11 Influence of calibration coefficient on concentration of SO_2 emitted

4 Conclusions

The dynamic management and control system of automatic monitoring equipment for waste gas pollution sources can effectively monitor the fraud problems such as modifying the parameters of automatic monitoring equipment without authorization by enterprises, cut off the fraud channels such as modifying the working parameters of equipment, and reduce and eliminate the falsification of automatic monitoring data of most waste gas pollution sources, thereby improving the data quality and supervision efficiency of automatic monitoring of waste gas pollution sources.

This paper realizes the reverse control of environmental monitoring instruments through the network under the condition of man-machine distance, and realizes the remote collection of monitoring data, operation status and equipment parameters of on-site instruments. The accuracy and validity of online monitoring data can be judged according to the state of the instrument and equipment parameters. At the same time, through the dynamic supervision and revers control, the operation and maintenance management of on-site monitoring equipment can be realized remotely, which greatly improves the work efficiency.

The system has been operated by the Department of Ecological Protection of Shandong Province, and is proved to be practical, real-time and efficient, be able to make up for the shortage of manual inspection and comparison, and have a good application prospect in the field of environmental monitoring.

The innovation of this paper is as follows. The system realizes the "three simultaneous" monitoring of the monitoring data, operation status and parameters of automatic monitoring equipment by transforming the on-site automatic monitoring equipment and data acquisition and transmission instrument, eliminates the phenomenon of falsification by modifying equipment parameters, and judges the validity and accuracy of on-line monitoring data by remote random collection of monitoring instrument working status and equipment parameters. The upload of working status provides strong technical support for the operation and maintenance of on-line monitoring equipment. Through the reverse control function of real-time sampling, returning to zero and calibration, an efficient remote control means is provided for the management and control of online monitoring equipment.

References

[1] LU T. Development and application of the regional air quality early warning and joint action system in Yangtze River Delta for Shanghai EXPO [J]. Environmental Monitoring in China, 2013, 29(1): 141 – 146. (in Chinese).

[2] HU SY, CHANG Q, ZHANG DL, *et al.* The remote environment of inspecting and managing system based on wireless communication[J]. Control & Automation, 2004(3): 48 – 50. (in Chinese).

[3] BIAN QQ, XU Y, JIANG LZ. Environment monitoring instrument's reverse control system based on network[J]. Control & Automation, 2009, 4 – 1(25): 33 – 34. (in Chinese).