International Journal of Smart Home
Vol. 9, No. 12, (2015), pp. 267-278
http://dx.doi.org/10.14257/ijsh.2015.9.12.27

Implementation of Textile Air Conditioning Intelligent Monitoring System Based on Internet of Things

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Abstract

The traditional textile enterprise air conditioning system has deficiency such as temperature and humidity adjusting by manual work, low degree of automation, information management relative lagging and large error. According to the information management needs of modern textile, this paper design temperature and humidity monitoring system based on internet of things. The system is composed of three parts of remote monitoring subsystem, database subsystem and local monitoring subsystem. The system uses CC-LINK field bus, GPRS communication and computer network, and can control data remotely and on site. Combined with the characteristics of textile temperature and humidity, humidity priority control strategy is presented, and adaptive fuzzy-PID algorithm is adopted to tune the PID parameters on line. The results show that, the system dates transfer stability, temperature and humidity can be centralized and remote control, improving the level of enterprise information management, saving energy and reducing consumption.

Keywords*: Temperature and humidity，IOT，intelligent，CC-LINK*

1. Introduction

Material guarantee of obtaining high-quality cotton yarn depends on quality of cotton. Advanced cotton spinning technology as well as stable spinning temperature and humidity control system act as technical guarantee. Currently, temperature and humidity control automation level is low in some domestic textile enterprises. For example, air quantity of air transmission and returning fans, spraying quantity of water pump, etc. are manually controlled and adjusted according to experience of technical personnel, thereby controlling temperature and humidity. Technical personnel's sense of responsibility and technical level are different, in addition the monitored scope is larger, it is impossible to adjust temperature and humidity in real time one by one. Temperature and humidity can not be timely and accurately adjusted, and larger electricity waste can be caused due to full load operation; However, when the equipment fails, failures can be discovered and handled by personnel examination since there are no functions of automatic detection, alarm, data management, etc. Textile equipment has low automation and information-based level. Textile workshop temperature and humidity are often fluctuated in large scope, thereby leading to substandard product quality [1].

IOT (Internet of Things) belongs to a new generation information technology for highly integrating sensor, Internet, field bus, information processing and other technologies. IOT technology constructs new mode for intelligent, centralized and remote control management on textile industry with the transformation and upgrading of the textile industry. In the paper, textile air conditioning intelligent monitoring system based on IOT was designed and implemented, IOT technology, CC-LINK bus technology, computer network technology, mobile GPRS network and other technologies were applied to textile air conditioning monitoring management system. Equipment can be monitored,

ISSN: 1975-4094 IJSH

operated and managed in the site and remotely. IOT technology was introduced in the field of textile production, the traditional mode with labor mechanical control human as center was changed into the mode with intelligent information processing as center, thereby greatly enhancing management level of textile industry management, and greatly improving the production efficiency [2-3].

2. The Overall Scheme of Intelligent Monitoring of Internet of Things

Textile temperature and humidity intelligent monitoring system is mainly composed of field monitoring subsystem, database subsystem and remote monitoring subsystem. Design of each subsystem is relatively independent and mutually connected with good operability, extensibility and applicability as shown in the Figure 1.

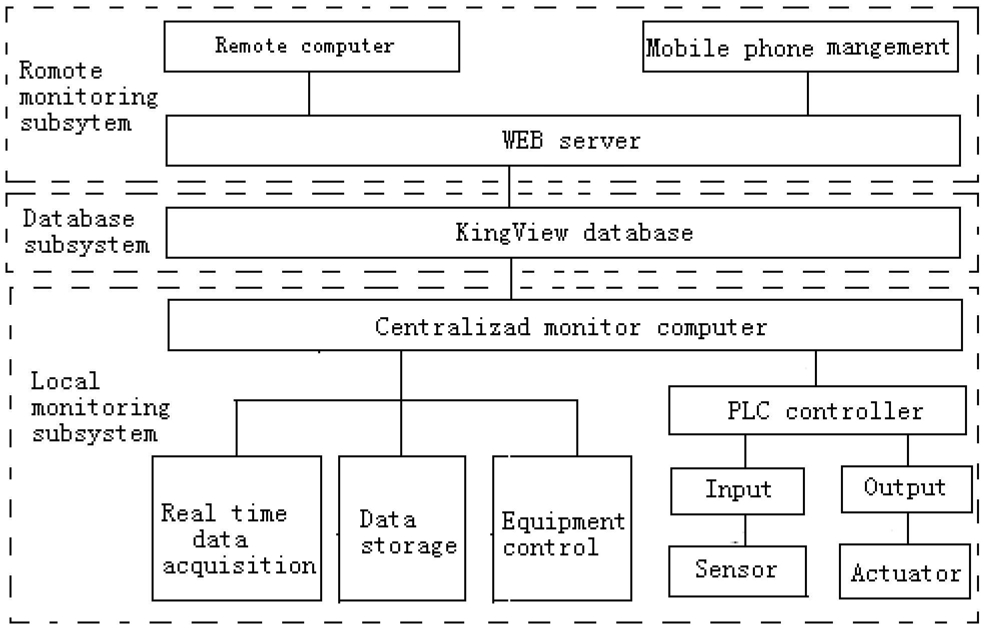


Figure 1. The Overall Diagram of Monitoring System Networking based on IOT

On-site monitoring subsystem can be adopted to detect temperature, humidity and other signals inside and outside the room and in the air supply room through temperature and humidity sensor, and digital signals are collected to central processing unit (CPU) PLC for processing. Actions of actuating mechanism can be controlled through comparing with set temperature and humidity values, thereby controlling executive components such as wind window, fan, water pump, etc. in real time, and realizing accurate control of temperature and humidity in workshop. Process parameters of all workshops, operation states of all equipment, all parameter history and real-time curves can be displayed through monitoring computer, failure alarm, etc. can be realized[3].

Database subsystem can store and process system data mainly through operating KingView OPC Server data service software. Data can be exchanged through remote monitoring subsystem and field monitoring subsystem as an open bridge.

Remote monitoring subsystem utilizes configuration software web publishing function in centralized monitoring computer, monitoring system can be connected into remote monitoring computer for monitoring, and related personnel can inquire and monitor with it. GPRS wireless communication mode also can be adopted for sending related abnormal information to handset of maintenance personnel in the form of short message, thereby maintenance personnel can respond immediately.

3. Design of Networking Communication System

3.1. Construction of CC-LINK Field Bus

Controlled object is a textile mill, which is composed of four workshops responsible for blowing, fore-spinning, spinning and spooling. Temperature and humidity control systems are separated from each other for several hundred meters, etc. in various textile workshops. Temperature control system of each workshop is composed of temperature and humidity sensor, motor, inverter, regulating valve, touch screen, PLC and other devices. Textile temperature control system center control room is uniformly monitored in a centralized mode. All workshops can achieve scattered control in the site. The whole temperature and humidity control system is connected and built on CC-LINK field bus, and system communication network structure design is as shown in the Figure 2.

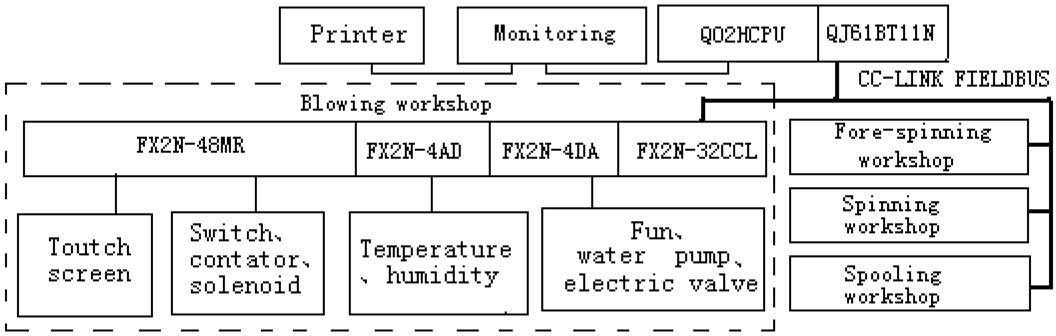


Figure 2. Field Bus System Structure Diagram

Main control room is set to be communication network master station of temperature and humidity control system. Though controlled points are not excessive as the main station, stronger information processing ability and faster communication rate are required. Mitsubishi Q02HCPU is selected as center controller PLC. Mitsubishi QJ61BT11N communication module is adopted main station communication module, which forms CC-LINK communication network with blowing, fore-spinning, spinning and spooling substations. It is connected with external central control host computer and printer, KingView SCADA monitoring software is installed in host computer for collecting operation information of all substations for real-time monitoring and remote control [4-5].

Temperature and humidity control stations of blowing, fore-spinning, spinning and spooling workshops are regarded as slave stations. Each slave station can collect temperature, humidity and other information, thereby controlling water pump, fan, heating tube and other equipment. Certain margin should be considered according to required switch quantity and analog quantity. FX2N-48MR PLC is selected in each substation; PLC is externally connected with FX2N-8AD analog input module.

Temperature and humidity analog quantity information is collected through D/A conversion. Meanwhile, it is externally connected with FX2N-8DA analog output module for adjusting rotation speed, air return quantity, etc. of fan and water pump, thereby maintaining indoor humidity and temperature stable. PLC of each slave station should be connected with FX2N-32CCL communication module externally, thereby forming CC-LINK bus network with master station, and realizing data exchange with master station communication module. SLC of slave station is externally connected with MCGS touch screen; related parameters can be set in the site for monitoring parameter operation of equipment.

3.2. Setting of the Network Hardware and Parameter

All master stations are connected with communication modules of slave stations through specialized communication cable with shielding function. Firstly, station numbers are set. The station number is set as ‘0’ on master station QJ61BT11N communication module. Station numbers are respectively set as ‘1, 3, 5 and 7’ on FX2N-32CCL communication modules of 1#-4# slave stations correspondingly [6].

Communication speed is set then, all slave stations are far away from each other, the communication speed is set as ‘0’ (156 KBPS), communication distance is 1.2 km long, which meets the design requirements. Main communication parameters are set in the master station PLC. Mitsubishi GX-Developer main interface is opened, and CC-Link network parameters are selected for setting. Station type, mode, remote input and output refreshing software and other parameters are mainly set. Main parameter setups are shown in Table 1 and Table 2.

Table 1. Setting of the System Network Parameters

Name	Start I/O	Type	Connection number	remote RX
Setting value	0	master station	5	X1000

Table 2. Setting of the System Network Parameters

Name	Remote RY	Remote RXr	Remote RYw	Number of replication
Setting value	Y1000	D800	D900	3

Wherein, starting I/O is the location of QJ61BT11N communication module station, wherein the type is master station. The master station is connected with four substations. Five stations are totally connected into network. Remote RX and RY are starting addresses of master station and substation for switch quantity parameter exchange. Remote RXr and RYw are starting address of master station and substations for numerical quantity parameter exchange. Network reconnecting frequency is set as 3 during communication error.

3.3. Distribution Buffer Register

FX2N-32 CCL communication module can exchange data between FX series PLC and CC-LINK network master station through built-in buffer register. FX series PLC can write data from other FX PLC into special storage device through to instruction, data can be received and then transmitted to master station [7].

The data can be read out from special storage device through from instruction. Data transmitted from master station can be read into programmable controller. In the design, more analog quantities should be exchanged from all substations, thereby remote equipment communication module of each substation occupies two stations, meanwhile, 8 analog quantity data can be exchanged at the same time, setup of remote input and output relays as well as contacts of all substations are shown in Table 3.

Table 3. Allocations of CC-LINK Network Relay Buffer and Register

Name	Master station	Blowing	Fore-spinning	Spinning	Spooling
RX	X1000	X1000-X1063	X1064-X1127	X1128-X1191	X1192-X1255
RY	Y1000	Y1000-Y1063	Y1064-Y1127	Y1128-Y1191	Y1192-Y1255
RWr	D800	D800-D807	D808-D811	D812-D815	D816-D819
RWw	D900	D900-D907	D908-D911	D912-D915	D916-D919

3.4. Database Subsystem

Database is set between remote monitoring subsystem and site monitoring subsystem, which acts as communication bridge. In the paper, on-site monitoring database based on KingView is adopted in the paper. Processed real-time environmental data, equipment status information and control logs, etc. are stored in the database by the system, on-site and remote equipment control, inquiry of previous statements, etc. are established on the basis of database. Database subsystem can be adopted for showing information stored in database to remote users on one hand, control command of remote users also can be delivered to site subsystem on the other hand, thereby controlling site temperature and humidity systems remotely[8-9].

3.5. Remote Monitoring System

Remote monitoring subsystem is mainly adopted for realizing remote collection of temperature and humidity information and control command delivery with functions of real-time environment information preview, user registration management, historical data query and derivation, equipment remote control, etc., therefore remote management and maintenance personnel can conveniently obtain site temperature and humidity information. Various monitoring means are provided for enhancing their initiative and intervention ability. Structure based on remote monitoring subsystem is shown in Figure 3.

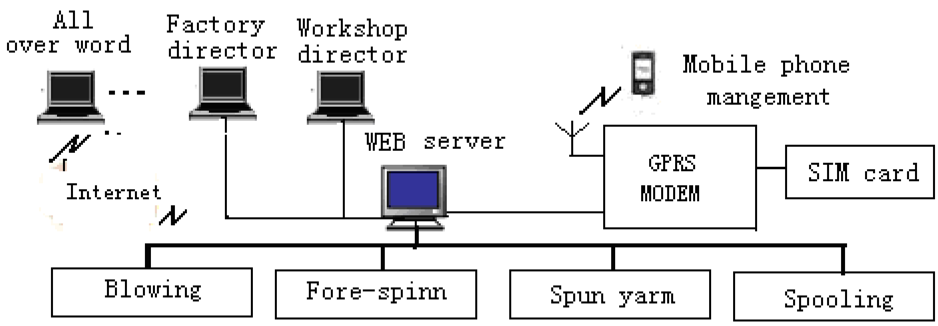


Figure 3. Remote Monitor System Structure

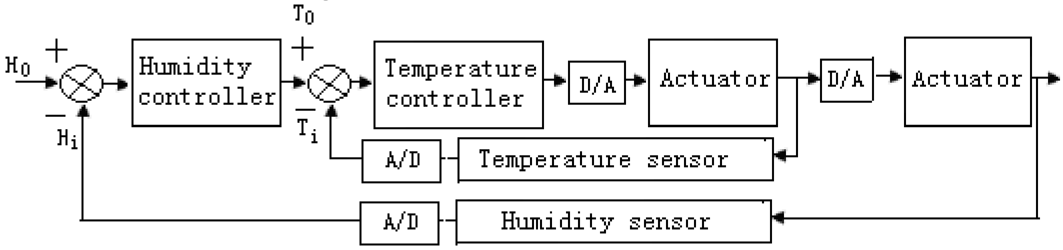
Two modes are mainly adopted in remote monitoring subsystem. Mode 1: King view 6.55 provides Web publishing function for remotely viewing configuration screen. http://192.168.1.100/KingViewWeb is input in browser address bar of remote monitoring terminal. Monitoring menu, the same as KingView operation system of host computer also can be obtained. It can keep synchronous with the host machine. Real time transmission of workshop data, communication status display, workshop temperature and humidity value, parameter status of all actuators in workshop, process temperature dynamic display, remote alarm, etc. also can be realized remotely[10].

All management personnel and engineers can remotely control field devices. Mode 2: GrmOpcSMS data management software is installed on the host computer, SIM card is installed on SMS alarm. Related data can be read from King view software of server by OPC interface. The data can be handled through set alarm condition. System alarm message can be sent to handsets of relevant maintenance personnel, thereby related personnel can comprehend alarm information immediately, and failures can be handled timely.

4. Temperature and Humidity Control Strategy

4.1. General Design

Temperature and humidity control process is characterized by time varying, non-linearity, more interference, strong coupling, large inertia, etc. Humidity and temperature humidity will influence each other. If one parameter is changed, the other also can be changed to certain extent. Certain fluctuation is allowed in workshop temperature aiming at spinning temperature and humidity control. However, it must firstly meet e requirements of labor protection. However, relative humidity of workshop should be strictly controlled generally. Temperature and humidity cascade control is adopted in the system in line with the purpose of energy saving for meeting the requirement of textile technology. In addition, control strategy of humidity first and mechanism adjustment in stages should be implemented, namely temperature and humidity controllers are connected together in series. Output of temperature controller is adopted as input of humidity controller as shown in the Figure 4.



・**Figure 4. Temperature and Humidity Control Circuit Diagram**

□□□□□□□□□□□□□□□□□□□□□□ □Wherein, H_0 represents set humidity value, T_0 represents set temperature value, H_i represents actual humidity value, and T_i represents actual temperature. Actuator is composed of inverter, fan, regulating valve, etc. Different control strategies are adopted according to different temperature and humidity operation environments [11].

For example, when the relative humidity is low and air is dry, sampling value is compared with the set value, converter is controlled through PID regulator according to deviation, thereby improving rotation speed of water pump. Spraying quantity can be increased for improving air relative humidity. When the frequency and the maximum spraying quantity are adjusted to maximum values, saturated moist air delivery can be increased if the relative humidity is low, thereby further increasing workshop relative humidity. When humidity reaches requirement, temperature can be adjusted, the temperature can be controlled in regulated scope through adjusting air and return air ratio, heating, changing frozen water quantity and other measures.

4.2. Principles of Fuzzy PID Control

For temperature or humidity control, conventional PID controller does not have the online parameter tuning function and has stronger reliance on the accuracy of system models, as for a control system which is non-linear and time-varying and is subject to random interference, it is generally difficult to obtain good control performance. The performance can be greatly improved through combining fuzzy control and PID control [12].

As for temperature control, fuzzy PID controllers take temperature error e and error change ec of the compressor as input, firstly find out the fuzzy relationship of three parameters, e and ec of the PID controller, the system continuously detects e and ec., and three PID revised parameters K_p、 K_i and K_d are obtained according to the relevant fuzzy principles, and the three PID parameters are revised on-line continuously, thereby satisfying the demands of e and ec in different moments to PID parameters self-tuning, and targeted temperature or humidity can obtain good dynamic and static performances which is shown as Figure 5.

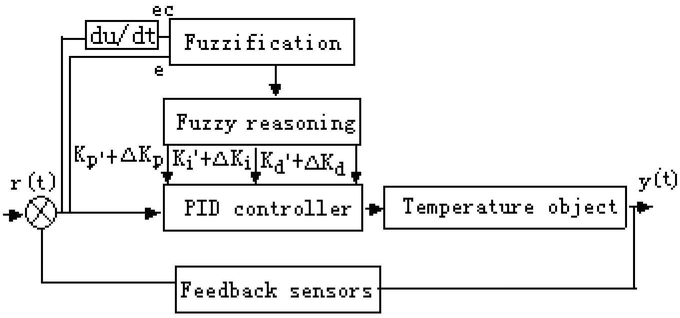


Figure 5. Fuzzy Adaptive PID Controller

4.3. Fuzzy Process

The basic theory domain of temperature error e and temperature error rate ec is set as[-3, +3], and discreted into seven grades that are [-3, -2, -1,0, +1 , +2, +3]. Fuzzy subsets correspond to ｛negative large, negative middle, negative small, zero, positive small, positive middle, positive small｝, denoted as ｛NB, NM, NS, ZO, PS, PM, PB｝.Temperature error e and error ec are used as the input of the adaptive fuzzy controller. PID parameters are modified on-line by the fuzzy control rules, and correction of PID parameters(ΔK_P 、ΔK_i 、ΔK_d)are used as output. PID parameters are also defined as ｛NB, NM, NS, ZO, PS, PM, PB｝, The triangle membership are designed around the zero value to guarantee the control sensitivity at small deviation.

Conventional PID controller does not have the online tuning function and has stronger reliance on the accuracy of system models, as for a control system which is non-linear and time-varying and is subject to random interference, it is generally difficult to obtain good performance. The performance of the control system can be greatly improved through combining fuzzy control and PID control.

4.4. Establishment of Fuzzy Control Strategy Table

Proportional coefficient has the function of accelerating system response speed, K_P is greater, the response speed is faster, but instability can be easily generated. K_P is smaller, the regulation accuracy can be lowered, the response speed is slowed, the system static and dynamic characteristics are deteriorated; Integral action is to eliminate the system steady-state error. K_i is greater, the speed of eliminating static errors is faster, but K_i is too large, initial saturation phenomena can be generated in the initial stage of response. However, K_i is smaller, and the system static error can not be easily eliminated. Differential role is to enhance the system dynamic characteristics and restrain deviation changes in the response process, K_d is bigger, the response process can be braked in advance, the system anti-jamming performance can be lowered. The core of fuzzy control design is to sum up practical experience in engineering design, and temperature fuzzy control rules of $\triangle K_P$、$\triangle K_i$ and $\triangle K_d$ are shown in Table 4.

Table 4. ΔK_P、ΔK_i、ΔK_d Fuzzy Control Rulers

ec / e	NB	NM	NS	ZO	PS	PM	PB
	$\triangle K_P/\triangle K_i/\triangle K_d$						
NB	PB/NB/PS	PB/NB/NS	PM/NM/NB	PM/NM/NB	PS/NS/NB	ZO/ZO/NM	ZO/ZO/PS
NB	PB/NB/PS	PB/NB/NS	PM/NM/NB	PS/NS/NM	PS/NS/NM	ZO/ZONS	NS/ZO/ZO
NS	PM/NB/ZO	PM/NM/NS	PM/NS/NS	PS/NS/NM	ZO/ZO/NS	NS/PS/NS	NS/PS/ZO
0	PM/NM/ZO	PM/NM/NS	PS/NS/NM	ZO/ZO/NS	NS/PS/NS	NM/PM/NS	NM/PM/ZO
PS	PS/NM/ZO	PS/NS/ZO	ZO/ZO//ZO	NS/PS/ZO	NS/PS/ZO	NM/PM/ZO	NM/PB/ZO
PM	PS/ZO/ZO	ZO/ZO/NS	NS/PS/PS	NM/PS/PS	NM/PM/PS	NM/PB/PS	NB/PB/PB
PB	ZO/ZO/PB	ZO/ZO/PM	NM/PS/PM	NM/PS/PM	NM/PM/PS	NB/PB/PS	NB/PB/PB

4.5. Fuzzy Reasoning

According to the actual situation of the system, the operation rules of the above system and the adjusting direction rules of PID parameters under different error conditions in the control system are combined, the PID parameters are respectively ratiocinated fuzzily according to mamdani reasoning method, thereby 49 fuzzy reasoning rules can be formed as shown in Table 4, and corresponding fuzzy relation can be obtained according to each rule such as fuzzy control rules to $\triangle K_p$.

$$R1: \text{IF } e=NB \text{ and } ec=NB \quad \text{THEN} \quad \triangle K_p=PB \tag{1}$$

Also can be listed, therefore, the fuzzy relation of the entire control rules corresponding to the whole system is:

$$R = R1 \vee R2 \vee R3 \vee \ldots \vee R9 \tag{2}$$

After the overall fuzzy relation R is obtained, as for input e and ec on some time, corresponding amount of u is obtained as follows:

$$u(k) = [e(k) \times ec(k)] \circ \tag{3}$$

The weighted average method is adopted to obtain corresponding output. When the control objectives are within the fuzzy self-adaptive range, fuzzy PID control is input, and after PID parameter revised amount $\triangle K_P$、$\triangle K_i$ and $\triangle K_d$ are obtained through fuzzy reasoning; PID is adjusted after processing according to the following formula:

$$K_p(n) = K_p(n-1) + \Delta K_p \tag{4}$$

$$K_i(n) = K_i(n-1) + \Delta K_i \tag{5}$$

$$K_d(n) = K_d(n-1) + \Delta K_d \tag{6}$$

Where in ，K_p(n)、K_i（n） and K_d（n）are the current on-line tuning values, K_p（n-1）、K_i（n-1） and K_d（n-1）are initial PID tuning values, and $\triangle K_p$、$\triangle K_i$ and $\triangle K_d$

are fuzzy adaptive output revision values.

4.6. Reverse Fuzzy Processing

In practical control, after K_p、K_i and K_d are turned in real time on-line, the output is processed through adopting a discretization method:

$$\mu(k) = K_p e(k) + K_i \sum_{i=0}^{k} e(i) + K_d ec(k) \tag{7}$$

In the formula, u(k) is the control output, e(k) is the system error, ec(k) is the system error variation, K_p、K_i and K_d are proportion, integral and differential coefficients after tuning. Accurate output amount U can be obtained through multiplying output u(k) by corresponding scale factor Ku for controlling the temperature change.

As for the humidity control, we adopt the same similar fuzzy control technology, and can acquire the same effect.

5. Analysis of Optimization Effect

The transformation is mainly based on the purpose of improving running performance and communication networking ability of traditional textile air conditioning system. CAN bus and other communication networks can be selected on the market aiming at system IOT platform in the aspect of selecting communication networking mode. Though the cost is lower, it has relatively weak anti-interference ability and higher failure rate [13]. On-site online communication network structure based on CC-LINK is characterized by simple structure, stable performance and strong anti-interference ability, which is suitable for small and medium sized automatic production line systems. Temperature and humidity systems in single workshop can be reformed, etc. aiming at IOT technology reforming for textile air conditioning system. One enterprise is adopted as example, fan, water pump and other equipment can undergo frequency conversion reform at the same time during IOT reform. By using above control technology, we can control the temperature and relative humidity in the set value, and has better rapidity and stability, better control effect. Reform effect technical index analysis is shown in Table 5.

Table 5. Technical Index System Before and After Reconstruction

Name	Temperature precision	Humidity precision	Power saving rate	Adjust way	Communication network
Before	$\pm 1.4^{O}C$	$\pm 5\%$	high	artificial	artificial monitoring and management
After	$\pm 0.8^{O}C$	$\pm 2\%$	reduce 20%	automatic	IOT, on-site and remote monitoring

Table 5 shows that traditional manual operation of traditional textile air conditioning as main production mode is changed after reform, operation of production equipment is mainly based on automatic control. Remote monitoring and maintenance can be realized with easy operation. Maintenance personnel can be greatly reduced, thereby lowering labor intensity and labor cost. The control precision of temperature and humidity is high with small fluctuation range under automatic control mode. The system has obvious energy saving and consumption reduction effect. Various process parameters can be adjusted in a centralized mode or remotely by the reformed system according to technological requirements. Monitoring, inquiry and process optimization are integrated. Enterprise production management resources are shared. Technicians, scheduling personnel and management personnel at all levels can understand enterprise production situation in a timely manner, thereby making management decision, and greatly promoting enterprise information-based level.

6. Conclusions

In this paper, existing sensor technology, CC-LINK site bus and GPRS mobile communication technology are combined based on IOT technology. A textile air-conditioning temperature and humidity intelligent control integrated platform is proposed and designed. The platform can realize site and remote monitoring on critical parameters of temperature and humidity in the workshop. Workshop production environment can be improved, enterprise automation and information-based level can be improved, and enterprises can achieve obvious energy saving effect. IOT technology is one of main development directions in current information technology. IOT technology can be introduced into intelligent textile industry for accelerating change of traditional management mode by production generator in China textile industry. It can be developed to information-based and industrialization directions on one hand. Textile industry development also provides huge space for application of IOT technology on the other hand. IOT technology application in textile industry can greatly improve the automation level of the enterprise, increase production efficiency and economic benefits, and provide certain guiding role for automatic and information-based transformation in traditional textile enterprises.

Acknowledgement

This work is supported by scientific research funded project of Zhejiang Industry Polytechnic College (2015KYA001) and scientific research funded project of Science Technology Department of Zhejiang Province (2015C31128).

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