Scholar Publishing Group
Nature Environmental Protection
https://doi.org/10.38007/NEP.2023.040210
ISSN 2790-2684 Vol. 4, Issue 2: 92-102

Research on Energy-Saving Technology for Unmanned 5G Base Stations

Feng Xu[1], Cheng Feng[1], Chendong Zhou[1], Ran Shi[1], Yifn Liu[2], Shili Ru[3], Ruiyang Bao[4]

[1]*Ningbo Shanbei Technology Co., Ltd, Ningbo 315000, China*

[2]*Ningbo University, Ningbo 315000, China*

[3]*NingboTech University, Ningbo 315100, China*

[4]*Ningbo University of Finance & Economics, Ningbo 315175, China*

Keywords: 5G, Energy-saving, Fresh Air System, Intelligent Control

Abstract: With the continuous improvement of network standards, the internal power consumption of base stations is increasing, resulting in high costs for operators. In response to the current widespread issue of high energy consumption in 5G base stations, this article conducts overall design, hardware design, and software design of the base station energy-saving system based on the energy-saving principle of intelligent fresh air systems. The actual measurement results indicate that introducing a fresh air system and implementing intelligent control can achieve the goal of energy conservation.

1. Introduction

As an important node in mobile communication networks, communication base stations consume more and more power internally with the continuous improvement of network standards. The power consumption of base stations has become one of the important expenses for operators' operating costs. How to reduce the energy consumption of base stations has become an important research direction for operators and tower companies[1].

From a technical perspective, it has become particularly difficult to reduce the energy consumption level of equipment by improving the efficiency of internal communication devices in base stations[2]. The internal communication equipment of the base station generates a large amount of heat, requiring air conditioning and other cooling equipment to cool and dissipate heat for the base station. The energy consumption of these equipment accounts for a high proportion of the entire base station. Therefore, reducing the energy consumption of cooling equipment such as air conditioners and improving the PUE value of base stations has become a key research direction.

The most basic requirement for the energy-saving system of the base station is that its reliability should be higher than that of the controlled equipment, that is, it should not affect the normal

operation of the communication equipment in the station. At present, the main problem with the energy-saving system of base station air conditioning is insufficient reliability, which cannot meet the requirement of "100000 hours MTBF". Moreover, due to imperfect design, the system is unstable and generates significant unnecessary power consumption. The base station energy-saving system should leverage its intelligent advantages such as self diagnosis, self analysis, pre-alarm, data statistics, and data transmission to assist maintenance personnel in making correct decisions, or directly manage equipment to improve operational quality and maintenance level[3]. Currently, these have not yet reached satisfactory levels.

The energy consumption of existing base stations mainly comes from communication equipment, IT equipment, refrigeration systems, as well as power and lighting equipment, with air conditioning accounting for over 50% of the energy consumption[4]. At present, domestic and foreign research institutions mainly conduct research from the following aspects:

1) Energy saving of the main equipment of the base station. Grid the base station and perform idle shutdown on 2G/3G/4G stations; Adopting discontinuous emission technology to control energy consumption; Intelligent carrier frequency shutdown technology utilizes intelligent software and algorithms to achieve real-time control of base station traffic.

2) Energy saving of the base station air conditioning system. Including variable temperature setting technology for air conditioning, variable frequency transformation technology for air conditioning, and new air system technology.

3) Energy conservation of base station buildings. Including building insulation technology, insulation reflection technology, battery burial technology, etc.

It has become quite difficult to improve the work efficiency of the main equipment of the base station through technological means in the future, while traditional building energy-saving technology has reached a bottleneck period[5]. In the future, the main way to achieve base station energy-saving is to reduce the energy consumption of the air conditioning system.

2. Energy Saving Principle of Intelligent Fresh Air System

The intelligent fresh air system is an intelligent fresh air air conditioning unit that provides air circulation, air filtration, and cooling temperature control to the communication room or base station[6]. The intelligent fresh air system itself does not have any refrigeration equipment, and utilizes the environmental temperature difference between the inside and outside of the room to achieve heat exchange between the inside and outside cold and hot air to achieve cooling. The intelligent fresh air system can be used independently, It can also be combined with other major refrigeration and air conditioning devices to form a computer room air conditioning system.

The energy saving principle of intelligent fresh air system is shown in Figure 1. It is based on the temperature difference between the outside and the inside of the computer room. The fan exchanges heat between the external cold air and the hot air emitted by the internal equipment in the computer room, and at the same time, the exchanged indoor hot air is discharged. During the exchange, the indoor air temperature in the computer room is reduced, resulting in a decrease in the temperature of the entire computer room, thereby reducing the utilization rate of air conditioning and achieving the goal of energy conservation. During this process, outdoor air is purified through an air filter and enters the interior of the computer room, so it will not affect the cleanliness of the air inside the computer room. The intelligent fresh air system mainly consists of intelligent controllers, air filter elements, indoor intake fans, outdoor exhaust fans, environmental monitoring sensors, and computer room air conditioning. The controller is the core of the system, which collects, stores, calculates, and processes various environmental parameters outside the computer room through various ports. According to the set parameters, it controls the operation of the indoor and outdoor

fans and air conditioners of the energy-saving system. It utilizes the exchange of natural air inside and outside the external environment to achieve indoor temperature regulation, thereby reducing the startup time of the air conditioner and achieving the goal of energy conservation and consumption reduction. The air filter is mainly used to ensure the cleanliness of indoor air and filter out small dust entering the air. The main function of the indoor air intake fan is to introduce cold air from the outside into the room, and reduce the temperature through heat exchange of the air. The main function of outdoor exhaust fans is to exhaust the indoor exchanged air and the hot air inside the machine room outside the machine room, achieving the goal of accelerating air circulation and improving air exchange efficiency. Environmental monitoring sensors are used to collect temperature and humidity parameters inside and outside the computer room, providing environmental data for the controller[7].

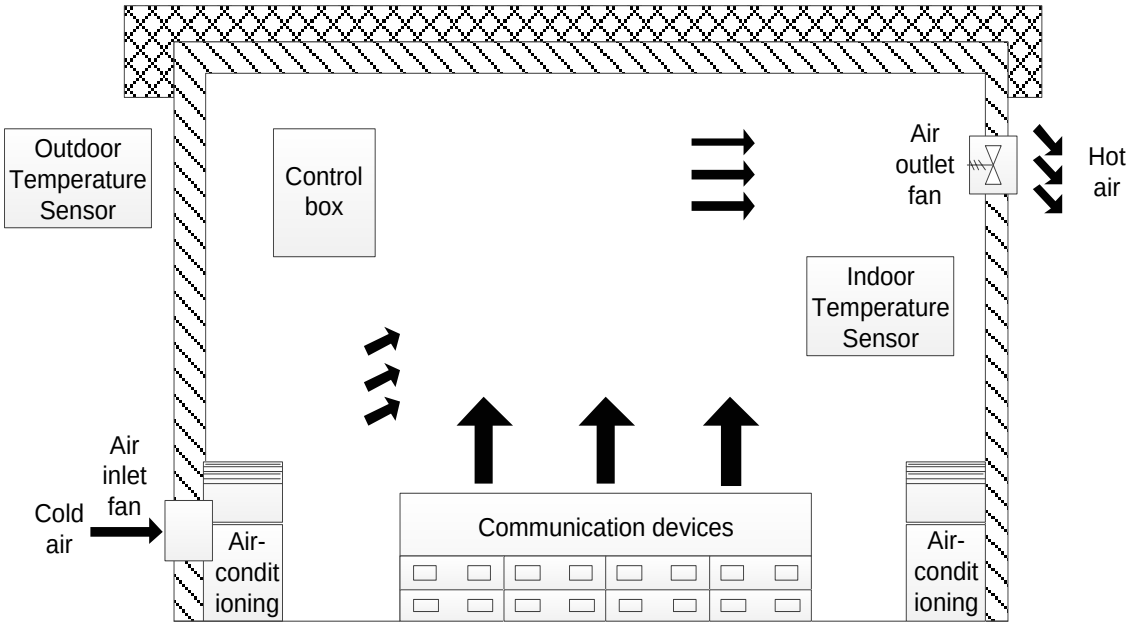

Figure 1. Energy saving principle of intelligent fresh air system

3. Overall Design of the Base Station Energy Saving System

According to the "Maintenance and Operation Regulations for Mobile Communication Power and Supporting Facilities", the temperature of the base station should be maintained between 10 and 35 ℃, and the relative humidity should be maintained between 10% and 90%. In order to ensure the normal operation of the base station communication equipment, the designed base station energy-saving system must ensure that the indoor temperature is generally controlled at around 25 ℃ and the indoor humidity is controlled between 10% and 90%.

The energy-saving system components of the base station utilize the temperature difference between indoor and outdoor temperatures to form heat exchange, relying on a large amount of outdoor cold air and effectively transferring the heat inside the base station outward through fan exhaust, achieving indoor heat dissipation. This significantly reduces electricity consumption and operating costs, and extends the service life of air conditioners. The overall design block diagram of the base station energy-saving system is shown in the Figure 2. The main components include: control module, power supply, sensor, fan, baffle, air conditioning, buttons, LCD display, and wireless communication module.

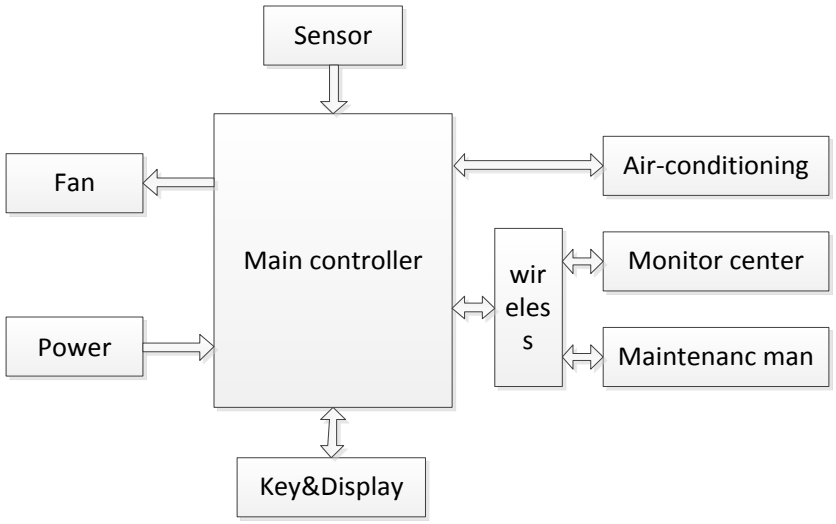

Figure 2. Overall design diagram of base station energy-saving system

From the functional block diagram of the base station energy-saving system, it can be seen that the base station energy-saving system is mainly composed of five parts: control module, sensor module, button display module, power module, and wireless communication module[8]. Introduction to the functions of each module:

Control module: composed of MCU, relay, fan, baffle, air conditioner, etc. A micro controller with model C8051F020 was selected as the control chip, and four small high-power electromagnetic relays with model JQX-13F were used to control the fan and baffle. The main function of the control module is to receive temperature and humidity signals collected by sensors, interrupt signals from button modules, and control commands from wireless modules, process and analyze signals, send commands to control the operation of dampers, fans, and air conditioners, and regularly send the temperature and humidity of the base station and the working status of fans, dampers, and air conditioners to the display module and wireless communication module;

Sensor module: Two DS18B20 temperature sensors and one DHT21 digital temperature and humidity sensor are selected to collect the indoor and outdoor temperature and humidity of the base station, and send signals to the control module.

Button display module: This module is designed with 4×4 matrix keyboard with 12864 LCD display. The main function is to set the password of the energy-saving system and the system parameters of the baffle, fan, and air conditioning on/off through the keyboard. The 12864 LCD displays indoor and outdoor temperature, indoor humidity, and the working status of the baffle, fan, and air conditioning.

Power module: The system requires 12V, 5V, and 3.3V DC power supplies. So choose a switch power supply with model JMD70-125 to provide 12 and 5V DC power supply for the system board. After voltage conversion circuit, obtain the required voltage for each module.

Wireless communication module: SIM900A chip is selected to transmit the signals transmitted by the control module to the information collection and detection system of the monitoring center and maintenance personnel. It can also receive control signals from the monitoring center and maintenance personnel and transmit them to the control module.

Monitoring center: stores the information transmitted by the wireless communication modules of each base station, can query the daily information of each base station, and can transmit control instructions from operators to the wireless modules of the base station that need to be controlled.

Maintenance personnel: Accept the system operation information transmitted by the wireless

module, and can also send instructions to the wireless module to control the system operation status.

4. Hardware Design of Base Station Energy Saving System

After receiving temperature and humidity signals collected by sensors, interrupt signals from button modules, and control commands from wireless modules, the control module processes the signals and sends commands to control the opening and closing of the baffle, fan, and air conditioning. The temperature and humidity signals from the base station are transmitted to the display module and sent to the wireless communication module[9]. The control module includes MCU, optocoupler isolation circuit, relay drive circuit, and comparator circuit.

The Figure 3 shows the circuit of the C8051F020 microcontroller, with TMS, TDO, and TDI being JTAG download ports. RST is the reset port. ALE, nRD, and nWR are timing ports that control LCD reading and writing. Pins SEL0~SEL3 and REL2~REL3 are the I/O ports controlled by the matrix keyboard. Pins AD0 to AD7 are the data ports of the LCD. TXD0 and RXD0 are communication ports used for serial communication of SIM900A. The communication serial ports TXD1 and RXD1 are expansion ports used for RS485. J9 is a plug used to control relays. P2.1~P2.7 are data ports used for expansion. The analog input port is suspended. XTA1 and XTA2 are crystal oscillator ports that provide a clock source for micro controllers.

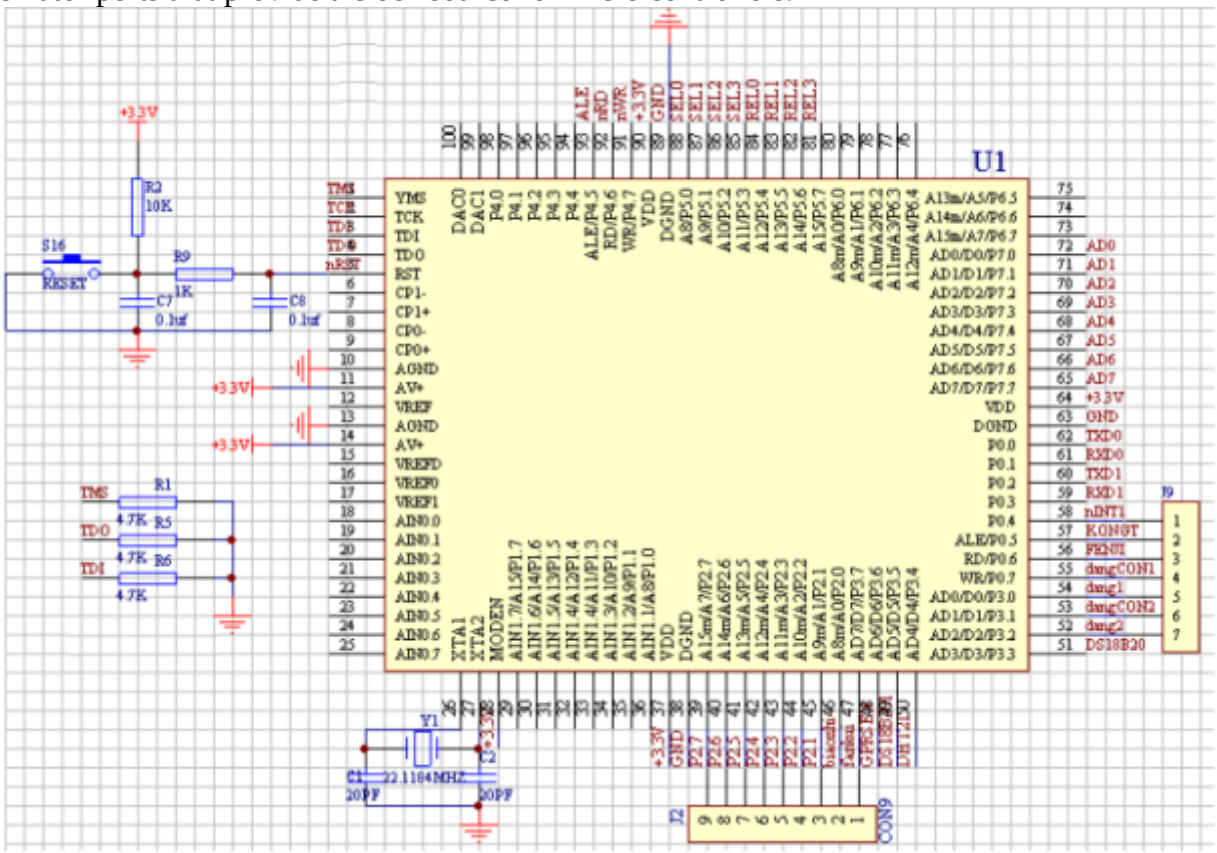

Figure 3. C8051F020 circuit diagram

The base station energy-saving system has been exposed to electromagnetic interference for a long time. In order to ensure stable and reliable operation of the system, the signal output between the circuits completely isolates the front-end from the load, reduces voltage interference, and minimizes circuit design[10]. The system uses an optocoupler which is show in Figure 4 to isolate the two power sources, ensuring the normal operation of the system.

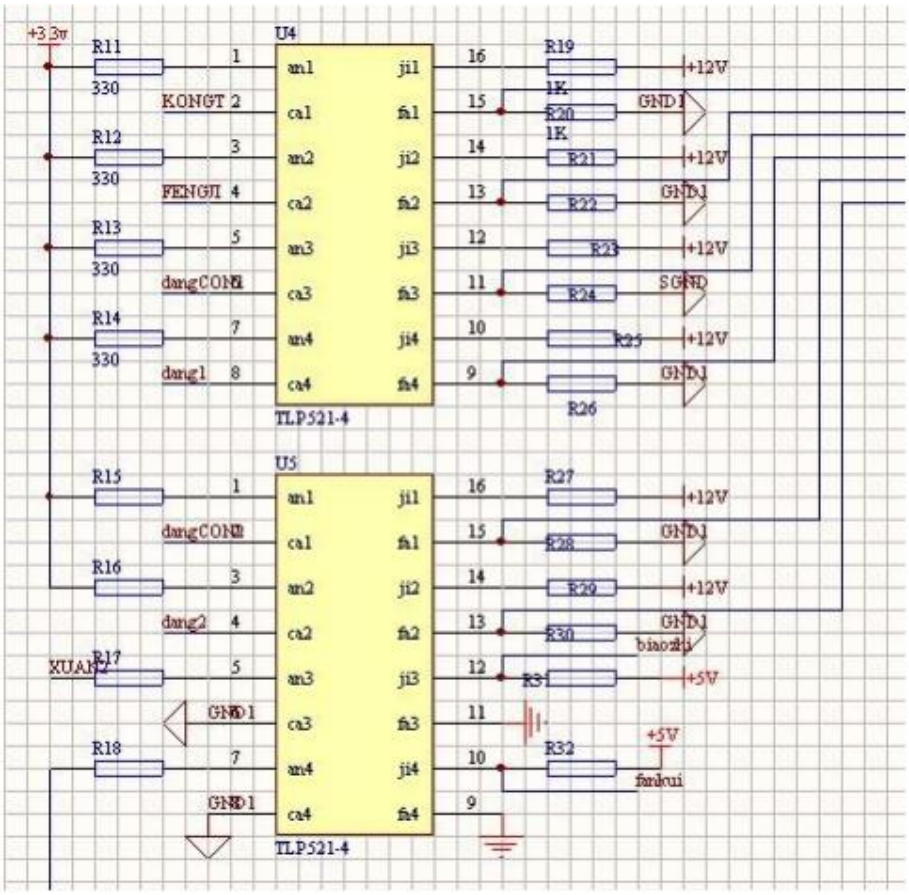

Figure 4. Optocoupler isolation circuit

When setting parameters, staff need to have an intuitive visual experience in order to know how many parameters are set and whether they are correct. Moreover, the system needs to display the current test temperature, humidity and other data, using the LCD 12864 LCD display module. The display module which is shown in Figure 5 displays the temperature, humidity, and operation status of the air conditioning and fan of the base station. The interface only jumps when the system is set; After the system settings are completed, it will return to this interface. If there are no button operations in the system within five minutes, the display module will automatically return to the interface displaying the status.

Figure 5. LCD displays the working status of the base station

5. Design of Energy-Saving System Software for Base Stations

The main function of the main program is to initialize the micro controller C8051F020 by sending control words and interrupts to each port of the micro controller after powering on. During idle time, it is used to display indoor and outdoor temperature, humidity, fan status, and air conditioning status. Other signals are collected and controlled through interruption.

After initializing the port, serial port, timer, and LCD, enter the password and system parameter values by pressing the keys, and then obtain the status of the sensor. Check the fan and if it malfunctions, immediately turn off the fan and turn on the air conditioning, and send a fault alarm to the control center and maintenance personnel; If the fan is not malfunctioning, perform automatic logic control, process buttons and displays, and regularly send data to the control center. Then, determine whether there is data on the serial port. If there is data, process the data; If not, directly send the system status to the PC, as shown in Figure 6.

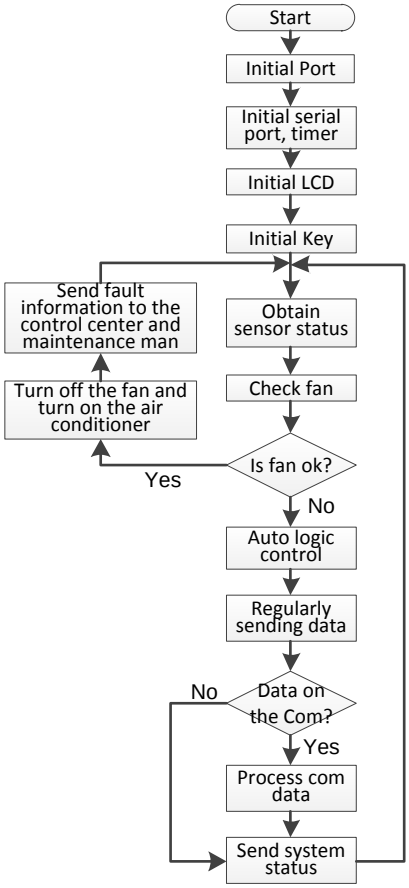

Figure 6. Main program flowchart

The control center and various base stations exchange information through sending and receiving text messages. Firstly, it is necessary to initialize the serial port and set the encoding method for sending SMS. The SMS sending and receiving system software encodes the SMS center address, destination address, and SMS information in PDU data format, and sends AT instructions to the SIM900A module to achieve message sending. The software process is shown in Figure 7. The received short messages include the sending number, time, and content. The received PDU format string must be decoded, and the obtained information must be compared with the parameter settings set in the software when the remote device experiences an abnormality to determine whether the device is working properly. If the remote device is working normally, directly store the information

in the database. Otherwise, send control commands to the remote device to achieve remote control, and at the same time, send abnormal information to the device management personnel. The software process is shown in Figure 8.

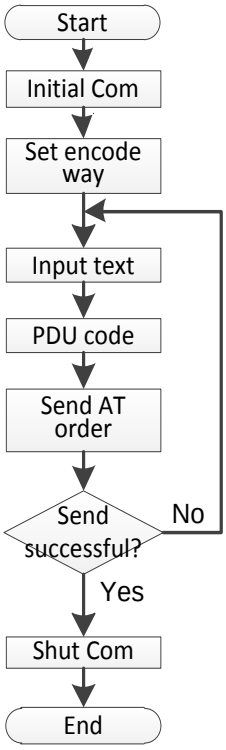

Figure 7. SMS sending process

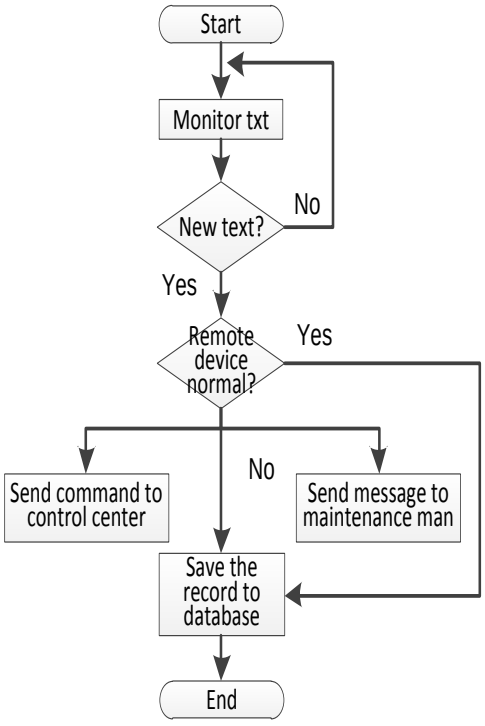

Figure 8. SMS reception and processing process

6. Energy Saving System Testing

In January 2023, an intelligent fresh air system was tested at a base station in a residential area in Ningbo. The test was conducted by turning on fresh air and air conditioning for one day. The registration data of the fresh air system is currently 30 days, and data is collected by a dedicated person around 5 pm. Among them, the data of the sub installed electricity meter: the 15 day electricity consumption of the fresh air system is 30 degrees, the 15 day electricity consumption of the air conditioning system is 119 degrees, and the total differential electricity consumption is 89 degrees. The data comparison details are shown in Table 1.

Table 1. Power consumption record table for base station air conditioning/fresh air equipment

Power consumption record table for base station air conditioning/fresh air equipment										
Base Station Name: Junsheng Feicuiwan Base Station in Ningbo High tech Zone										
NO	DATE	Electricity meter reading	Daily electricity consumption	AC. power consumption	AC. set temperature	outdoor temperature	indoor temperature	AC. status	Fresh air status	Difference in electricity consumption
1	2023/1/01 16:56	226614	--	12	28	0	22	OFF	ON	--
2	2023/1/02 16:59	226866	252	20	28	1	23	ON	OFF	8
3	2023/1/03 17:02	227110	244	21	28	3	22	OFF	ON	1
4	2023/1/04 16:59	227362	252	29	28	2	22	ON	OFF	8
5	2023/1/05 16:56	227612	250	30	28	3	25	OFF	ON	1
6	2023/1/06 17:02	227868	256	38	28	2	27	ON	OFF	8
7	2023/1/07 17:01	228117	249	40	28	0	25	OFF	ON	2
8	2023/1/08 17:03	228369	252	48	28	2	27	ON	OFF	8
9	2023/1/09 16:59	228615	246	50	28	0	25	OFF	ON	2
10	2023/1/10 17:02	228872	257	58	28	0	22	ON	OFF	8
11	2023/1/11 17:00	229118	246	59	28	0	25	OFF	ON	1
12	2023/1/12 16:53	229370	252	67	28	1	26	ON	OFF	8
13	2023/1/13 17:13	229620	250	68	28	0	22	OFF	ON	1
14	2023/1/14 16:50	229868	248	76	28	0	25	ON	OFF	8
15	2023/1/15 17:13	230121	253	78	28	0	22	OFF	ON	2
16	2023/1/16 16:55	230373	252	85	28	1	25	ON	OFF	7
17	2023/1/17 16:50	230625	252	87	28	0	24	OFF	ON	2
18	2023/1/18 16:51	230887	262	94	28	0	26	ON	OFF	7
19	2023/1/19 17:12	231141	254	96	28	4	24	OFF	ON	2
20	2023/1/20 16:59	231396	255	104	28	3	26	ON	OFF	8
21	2023/1/21 17:05	231650	254	106	28	-1	20	OFF	ON	2
22	2023/1/22 16:56	231902	252	114	28	4	26	ON	OFF	8
23	2023/1/23 17:03	232153	251	116	28	4	24	OFF	ON	2
24	2023/1/24 17:13	232410	257	124	28	2	27	ON	OFF	8
25	2023/1/25 16:58	232656	246	126	28	3	23	OFF	ON	2
26	2023/1/26 16:50	232913	257	135	28	4	21	ON	OFF	9
27	2023/1/27 16:56	233168	255	139	28	3	20	OFF	ON	4
28	2023/1/28 16:56	233428	260	147	28	5	26	ON	OFF	8
29	2023/1/29 16:47	233676	248	150	28	8	23	OFF	ON	3
30	2023/1/30 16:54	233932	256	158	28	6	27	ON	OFF	8

After testing and analysis, the intelligent ventilation system of the base station can achieve energy-saving goals, saving 89 kWh of electricity in half a month, with a power saving rate of

approximately 74.4%. In the Ningbo region, January, February, March, November, and December are the best months for the system to save electricity. Based on the annual operational capacity of 5 months, each base station can save 890 kilowatt hours of electricity annually, saving nearly 534 yuan in air conditioning electricity costs. According to the calculation of about 12000 self built base stations by Ningbo Iron Tower Company, it can save 6.4 million yuan in air conditioning electricity costs annually, and the energy-saving effect is very significant[11].

7. Summary

In response to the energy-saving needs of 5G base stations, this article combines IoT technology, artificial intelligence technology, and thermal design technology to conduct research on energy-saving and heat dissipation technology for unmanned 5G base stations. A energy-saving and heat dissipation technology is proposed, which can not only save a lot of electricity bills, reduce electricity costs, and reduce operating costs for Iron Tower Company, but also improve the stability and safety of communication equipment, and extend the service life of base station communication equipment.

Funding

2022 Ningbo Public Welfare Science and Technology Plan Project

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Guichard, Alex,How, "Cooling Technologies Will Help Pave the Way for the Future of 5G," Wireless Week, 2017, no.24.

[2] D. Peng, J. Zhou, S. Yi, "Prediction of Base Station Traffic Based on Spatial Cooperation Relationship," Computer Applications, 2019, 39 (1): 154-159.

[3] Yu Bao, Yonggang Li, Liang Zhao, Aijuan Zhang, Yutao Wang,MCEN, "Maximum cooperative equilibrium WSN based on greedy prediction to reduce opposite transmission," Computer Networks, 2023, vol. 221, no. 7 486-489.

[4] Song Xiaoqin, Miao Juanjuan, Lei Lei, Zhang Tianchen, "Maximum-Throughput Sidelink Resource Allocation for NR-V2X Networks With the Energy-Efficient CSI Transmission," Access, IEEE, 2020, vol. 8, 73164-73172.

[5] Q. Meng, L.Li, "Research on energy-saving new technologies for air conditioning used in communication base stations," Communication Power Supply Technology, 2019, 36 (S1): 110-113.

[6] Yumi Maeda, Yu Seshimo, Takashi Okazaki, "Study of a Cooling System for the Telecommunication Base Site," ASHRAE Transactions, 2005, vol.111, no. 2, 746-755.

[7] Wen He, Yizhe Zhang, Yihang Huang, Dazhi He, Yin Xu, Yunfeng Guan, Wenjun Zhang, "Integrated Resource Allocation and Task Scheduling for Full-Duplex Mobile Edge ComputingVehicular Technology," IEEE Transactions on, 2022, vol. 71, no. 6, 6488-6502.

[8] Hala B. Nafea, Mustafa M. Sallam, Fayez W. Zaki, "Study of DRX Sleep Mode Performance on Virtual Base Station Energy Saving in 5G Networks," Wireless Personal Communications, 2021, vol. 118, no. 4, 3251-3270.

[9] S M O'Connor, J P Lynch, A C Gilbert, "Compressed sensing embedded in an operational wireless sensor network to achieve energy efficiency in long-term monitoring applications," Smart material and structures, 2014, vol.23, no. 8, 85014-85014.

[10] Yanki Aslan, Jan Puskely, J.H.J.Janssen, Marcel Geurts, Antoine Roederer, Alexander Yarovoy, "thermal-Aware Synthesis of 5G Base Station Antenna Arrays: An Overview and a Sparsity-Based Approach," Access, IEEE, 2018, vol. 6, 58868-58882.

[11] Hengbo Xu, "Single-band tunable metasurface for thermal emitters in 5G bands," Optical Materials, 2022, vol.130.