ENERGY-SAVING MEASURES AND TEMPERATURE CONTROL FOR OUTDOOR COMMUNICATION CABINETS

by

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In view of the prominent and intractable problems of frequent high temperature alarms of the communication equipment and high energy consumption of air conditioners in Zhengzhou communication outdoor cabinets, a temperature control system with heat pipe as the main part and air conditioner as the auxiliary part is proposed in this paper. A prototype is developed and its applications are discussed. The annual field test shows the system works well, and it has a remarkable energy saving efficiency.

Key words: *communication cabinets, air conditioning, energy conservation, heat pipe*

Introduction

According to 2022 *China Internet Development Report*, the number of communication base stations in China has increased exponentially, and by the end of 2021, China built and opened a total of 1.425 million 5G base stations, and 9.96 million mobile communication base stations. According to 2021 *National Development and Reform Commission Report,* in 2020, China communication base stations consumed as much as 46.58 billion kilowatt-hours, especially after the commercial use of 5G in 2019, the energy consumption of 5G base stations increased greatly, among which the energy consumption of the temperature control system accounted for more than 40%, and a few base stations and data centers even reached 60%. Due to the integration of the three major operators (China Mobile, China Telecom, China Unicom), the communication equipment in the base station cabinet has increased greatly, so the load, and the power of 5G communication equipment is 3~5 times that of 4G, and the transformation from 4G to 5G results in the increase of the heat generation in the base station cabinet, where the airflow organization is unreasonable, and the cold capacity is not fully utilized, resulting in poor environmental temperature control in the communication base station cabinet. Communication equipment frequently alarms high temperature [1], therefore, reducing the energy consumption of communication cabinets and improving the temperature control efficiency of communication cabinets have become one of the hot spots in the field of communication.

Zhang, *et al*. [2] put forward a new type of mechanical refrigeration/loop heat pipe integrated air conditioning system for computer room, and made an experimental study on the performance of the system by using enthalpy difference test bench. Ma *et al*. [3] studied the

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operation performance of a heat pipe heat exchanger unit with pump drive circuit for heat dissipation in a small data center. Yue *et al*. [4] established a mathematics model of the micro-channel-separated heat pipe evaporator for the communication base station, and studied the heat transfer characteristics and flow mechanism under different filling rates. Ling *et al*. [5] developed a micro-channel separated heat pipe for the communication base station, and established a steady-state mathematical model to study its performance with experiment verification. Samba *et al*. [6] developed a thermosiphon loop equipment to cool the telecom equipment in outdoor cabinets, and conducted experimental research, the results showed that the maximum heat load of communication equipment using thermosyphon cooling system was twice that of the traditional cooling system. Meng *et al*. [7] put forward a hybrid cooling system of the heat pipe and mechanical refrigeration for the 5G communication base station, the experimental data showed that the energy consumption of the system varied with seasons. In order to solve the heat dissipation problem of the high heat density data center, Yang *et al*. [8] applied an oil cooling technology to thermal management of the data center, and found that the average cooling efficiency of the system increased by 66%. Wu *et al*. [9] put forward a new ventilation and cooling system of the communication base station, which combined a chimney ventilation with an air conditioning cooling system, an effective control strategy, its engineering applications achieved good economic and social benefits, and the air conditioning power consumption reduced by more than 50%. Now nanofluids are widely used in the cooling system to enhance the heat transfer [10-13], a suitable fractal boundary can also improve the heat transfer efficiency [14, 15], and hierarchically porous tubes are much promising for heat prevention, see discussions in [16-18].

Aiming at the cooling of outdoor communication cabinets all year round, the following way is often adopted world-widely, that is to use a single heat pipe cooling scheme. Although it makes full use of natural cold source and has high efficiency and energy saving, in summer and transitional season, when the outdoor temperature is high, the cooling supply is seriously insufficient and cannot reach the required temperature of communication equipment. A hybrid cooling system of heat pipe and air conditioner can not only improve the cooling efficiency, but also reduce the energy consumption of the cooling system. However, there is a loss in the cooling capacity transmission and distribution during the application process, and the working mode and airflow organization need to be further optimized, and the energy saving rate can be further improved. There is a lack of practical applications, and there is a lack of specific research on the cooling system of outdoor cabinets for communication. Based on the problems existing in the outdoor cabinet temperature control equipment of Zhengzhou Communication Company, a temperature control system with heat pipe as the main part and air conditioner as the auxiliary part was designed and developed, and its performance was tested in the field all year round.

Temperature control equipment for communication outdoor cabinets

Communication outdoor cabinets with a temperature control equipment use a heat pipe-based air conditioning system as the supplementary design scheme. The wind system circulation uses an internal circulation air supply mode. Firstly, the cabinet air with high temperature flows through the heat pipe of the heat exchanger for the cooling, secondly, it moves through the air conditioning evaporator for the further cooling, finally, the cooling air with low temperature enters into the cabinet and communication equipment for heat exchange, and a high temperature air is exported for cooling again. The multi-function integrated controller is connected to the temperature sensor, heat pipe cold end fan, pipeline fan, air conditioning compressor, condensing fan to control the working mode of the temperature control system. The working principle of temperature control equipment for communication outdoor cabinets is shown in fig. 1.

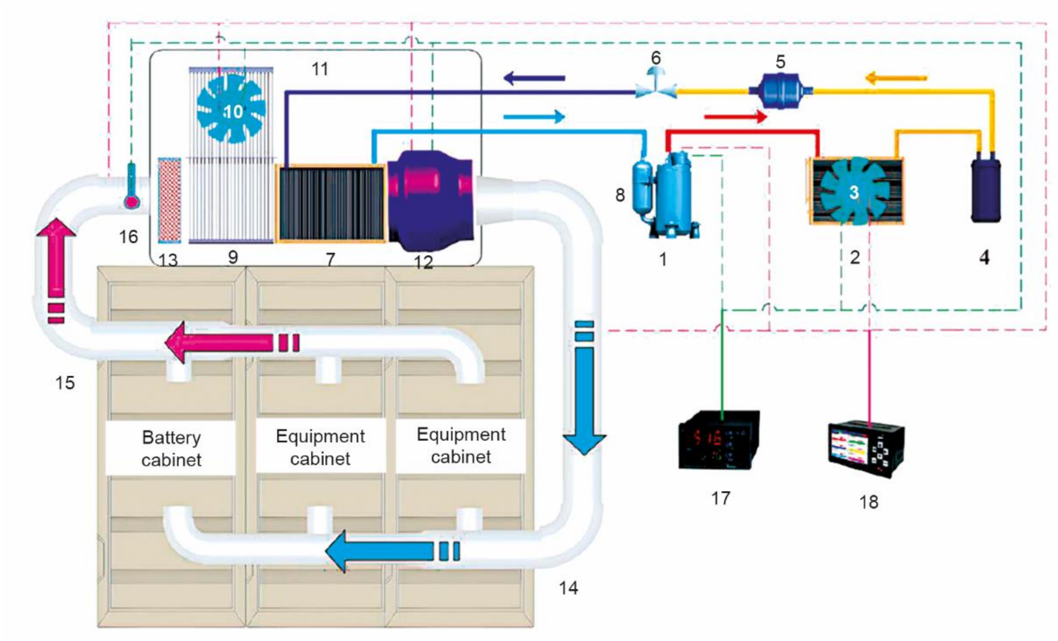

Figure 1. Working principle of temperature control equipment for communication outdoor cabinets;
1 – air conditioning compressor, 2 – condenser, 3 – condensing fan, 4 – reservoir, 5-filter drier, 6 – expansion valve, 7 – evaporator, 8 – gas-liquid separator, 9 – heat pipe, 10 – heat pipe cold end fan, 11 – equipment integration box, 12 – tube guide fan, 13 – filter dust screen, 14 – air supply pipe, 15 – return air duct, 16 – temperature sensor, 17 – controller, 18 – data collector

Experimental analysis

According to the working principle of temperature control equipment for communication outdoor cabinets and relevant national norms and standards, a prototype of temperature control equipment for communication outdoor cabinets (hereinafter referred to as the current temperature control equipment) was developed, which was applied to a three-in-one cabinet mobile communication base station in Zhengzhou City. After a year-round field test, the operation effect of the original door-mounted air conditioner (hereinafter referred to as the original temperature control equipment) was compared and analyzed, and the equipment cabinet using the original door-mounted air conditioner was referred to as the original equipment cabinet, and the upgraded equipment cabinet was referred to as the current equipment cabinet. The triple cabinet communication base station is equipped with three door-mounted air conditioners, each with a rated power of 600 W, a rated cooling capacity of 1800 W, a total rated power of 1800 W, and a total customized cooling capacity of 5400 W. The physical field diagram of the temperature control equipment is shown in fig. 2. At present, the prototype of temperature control equipment and measuring devices mainly include heat pipes, air conditioners, and feeding air ducts, controllers and data collectors. Table 1 shows the details. The total power of the current temperature control equipment is 1095 W, and the total heat exchange is 5435 W.

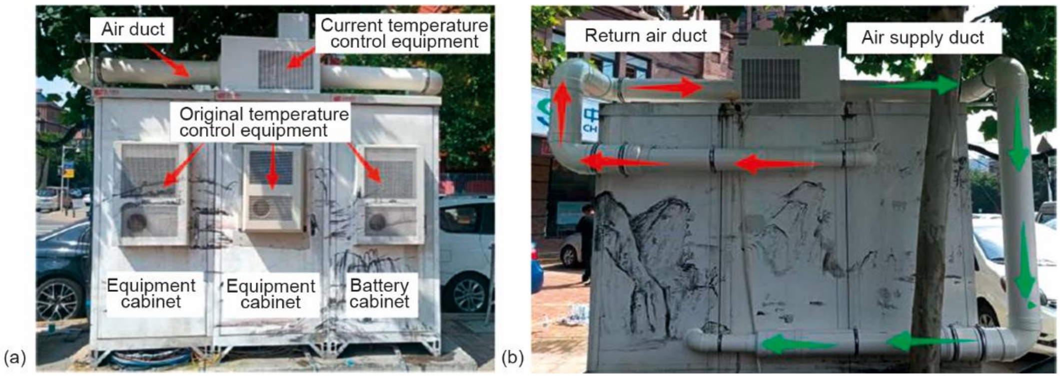

Figure 2. Physical site diagram of temperature control equipment

Table 1. A detailed list of temperature control equipment prototypes and measuring devices

Device name	Specifications and models	Manufacturer
Heat pipe	Heat exchange 3000 W, micro-channel parallel flow heat exchanger, heat pipe heat exchanger overall size: 18 mm/300 mm/300 mm, flat tube size: 1 mm/1.2mm/280 mm, number of flat tubes: 43. The condensing end is adapted to the axial fan YWF4E-300B with a power of 55 W	Self-restraint
Air conditioning	Working fluid: R134a, cooling capacity: 2435 W, and the power: 835 W	Self-restraint
Duct fans	EC092/25E3G01-B280/50S1-G315, air volume 1650 m^3/h, speed 2850 rpm, power: 205 W, maximum noise: 59 dB	German SPAL
Controller	AI-7 series high-performance intelligent thermostat, model AI-719P, 0.1 measurement accuracy	Jiangsu Jingchuang
Data acquisition instruments	KSF Series 8.1 inch 8CH paperless recorder, sampling accuracy 0.2FS%	Agilent, USA

The temperature control is of paramount importance in various engineering problems, Ma [19] suggested an optimal control model to control a working place temperature considering the unsmooth boundary, which was modelled by the two-scale fractal dimensions [20, 21]. Ma's method can be also powerfully applied to the present study.

The temperature control of the equipment cabinet of the original temperature control equipment and the current temperature control equipment under different outdoor environmental conditions throughout the year was tested. As shown in fig. 3, in the four seasons of the year, the temperature of the original equipment cabinet and the current equipment cabinet increases with the increase of outdoor temperature, the average daily temperature of the original equipment cabinet is 35.2 ℃, 49.1 ℃, 38.9 ℃, and 25.1 ℃ in the spring, summer, autumn and winter, respectively, and the average daily temperature of the current equipment cabinet is 28.7 ℃, 33.9 ℃, 32.1 ℃, 20.5 ℃ in the spring, summer, autumn and winter, respectively, which is 6.5 ℃, 15.2 ℃, 6.8 ℃, and 4.6 ℃ lower than the average daily temperature of the original equipment cabinet, respectively, therefore, the current temperature control equipment can better control the temperature of the equipment cabinet. The average daily temperature of the original equipment cabinet in summer is between 47~55 ℃, due to the high load in the base station cabinet, especially in the hot summer, and the airflow organization disorder, so that the ambient temperature in the cabinet is too high, the evaporation temperature of the original temperature control equipment is too high, the specific volume of compressor suction decreases, and the mass flow increases, resulting in larger compressor load, current overload, protective shutdown, and the ambient temperature in the cabinet further rises, so the communication equipment in the cabinet frequently appears high temperature alarm situation. In the transition season and winter average daily temperature control between 27~44 ℃ and 22~30 ℃, communication equipment will still have a small number of high temperature alarm situations. The current temperature control equipment in the four seasons of the year control equipment cabinet daily average temperature between 10~38 ℃, fully in line with the national mobile communication base station cabinet temperature control requirements, and communication equipment year-round no high temperature alarm.

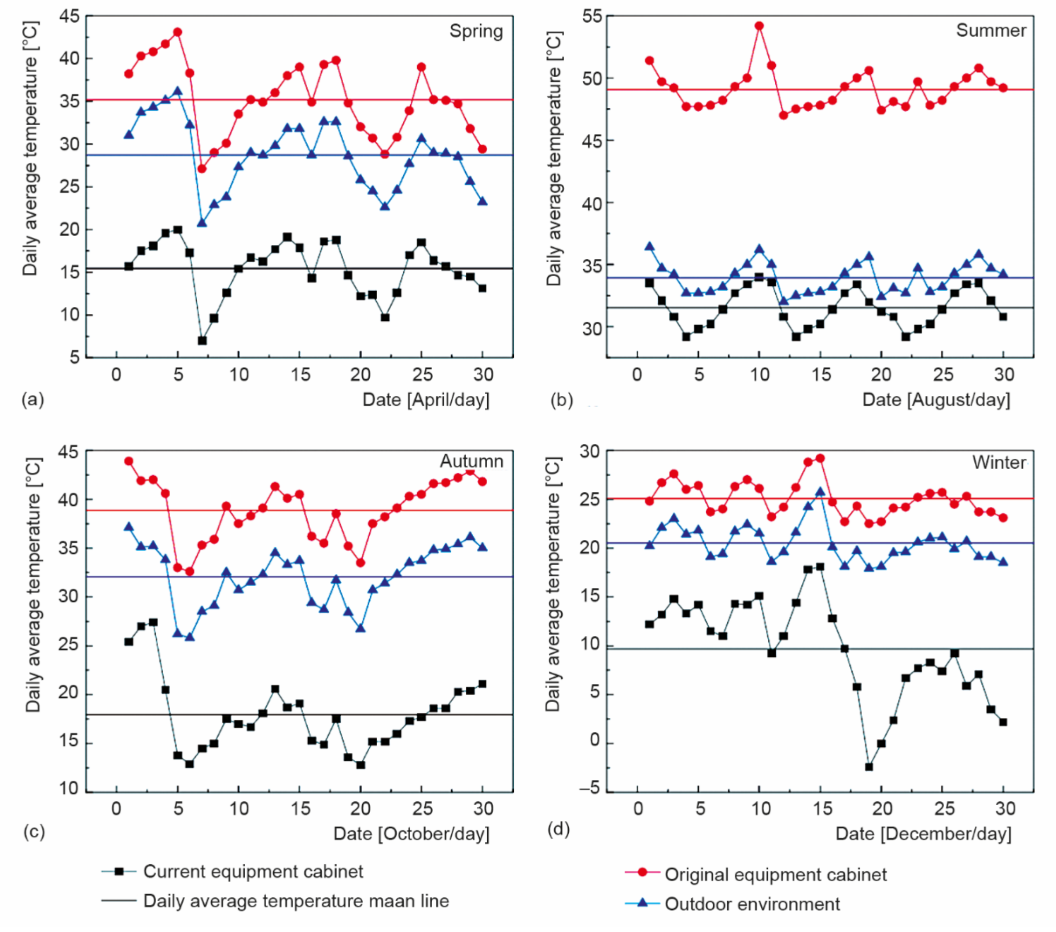

Figure 3. Comparison chart of the average daily temperature of the equipment cabinet

After the field test throughout the year, the power consumption of the current temperature control equipment and the original temperature control equipment was compared, and it can be seen from fig. 4 that the power of the original temperature control equipment and the current temperature control equipment increased with the increase of outdoor temperature day by day, and the average daily power of the original temperature control equipment in spring, summer, autumn and winter was 665.5 W, 1440.3 W, 753.0 W, and 637.0 W, respectively. At present, the average daily power of the temperature control equipment in spring, summer, autumn and winter is 211.7 W, 764.0 W, 265.5 W, and 156.3 W, respectively, which is 453.8 W, 676.3 W, 487.5 W, and 480.7 W lower than the daily average power of the original temperature control equipment. The daily average power of the current temperature control equipment has been greatly reduced, because the original temperature control equipment has been running almost all year round, resulting in excessive energy consumption, and the current temperature control equipment has reduced the operating time of the air conditioning compressor by setting a reasonable control logic to control the linkage operation of the heat pipe and the air conditioning system, and most of the days in the winter and transition season can meet the temperature control requirements in the cabinet by only relying on the heat pipe operation, so the energy consumption is greatly reduced. It can be seen from fig. 5 that the average daily power consumption of the original door-mounted air conditioner in spring, summer, autumn and winter is 16.0 kWh, 34.6 kWh, 18.1 kWh, 15.3 kWh, and the annual power consumption is 7551.0 kWh, and the average daily power consumption of tempe-

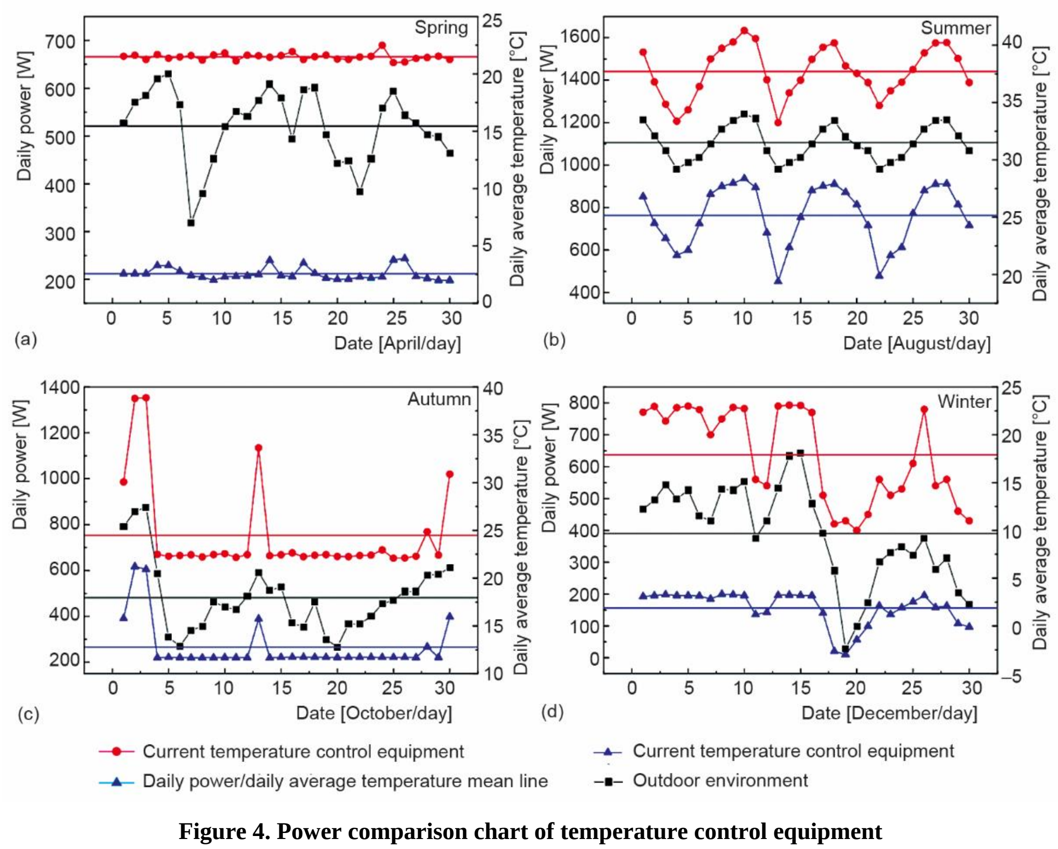

Figure 4. Power comparison chart of temperature control equipment

rature control equipment in spring, summer, autumn and winter is 5.1 kWh, 18.3 kWh, 6.3 kWh, 3.75 kWh, and the annual power consumption is 3018.4 kWh. Compared with the original temperature control equipment, the energy rate of the current temperature control equipment in spring, summer, autumn and winter is 68.2%, 47.0%, 64.7% and 75.5%, respectively, and the annual energy saving rate is as high as 60.0%.

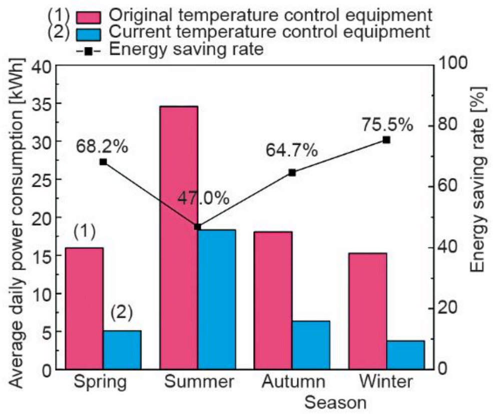

Figure 5. Comparison of daily average power consumption and energy saving rate in each season

Discussion and conclusion

In view of the current outstanding problems such as frequent high temperature alarm of the communication equipment and high energy consumption of air conditioners, the temperature control system based on heat pipes and supplemented by air conditioning is adopted, and applied to a three-in-one cabinet mobile communication base station in Zhengzhou City, after field testing throughout the year, compared with the original temperature control equipment, the operation efficiency of the upgraded and transformed current temperature control equipment is analyzed as follows.

- The temperature of the temperature control equipment for the communication outdoor cabinet is 10~38 ℃, which fully meets the temperature control requirement of the national mobile communication base station cabinet, solves the high temperature alarm problem of the equipment in the base station cabinet, and ensures the stable operation of the equipment in the communication outdoor cabinet.
- The average daily power of the current temperature control equipment has dropped significantly, and the energy-saving rates of the spring, summer, autumn and winter seasons of the temperature control equipment for communication outdoor cabinets are 68.2%, 47.0%, 64.7%, and 75.5%, respectively, and the annual energy saving rate is as high as 60.0%, and the energy-saving efficiency is very significant, and it is worth promoting and applying in Henan province, China.

In future, a mathematical model for this energy-saving technology is much needed, and the fractional calculus [22-25] might be one of the potential candidates.

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