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CONSTRUCTION, INSTALLATION AND PROTECTION OF TELECOMMUNICATION CABLES IN PUBLIC NETWORKS

Network infrastructure best practices

ITU-T

International Telecommunication Union

Summary

This Technical Paper has been developed to introduce high-efficiency network infrastructure solutions, including high-efficiency power solutions, renewable energy solutions, free and economized cooling solutions and energy-saving air conditioner cooling solutions. For every solution, a definition, principles, features and application conditions are introduced.

Change Log

This document contains Version 1 of the ITU-T Technical Paper on "*Network infrastructure best practices*" approved at the ITU-T Study Group 5 meeting held in Lima, 2-13 December 2013.

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1 Introduction

1.1 Purpose and scope of this Technical Paper

This Technical Paper has been developed to introduce high-efficiency network infrastructure solutions, including high-efficiency power solutions, renewable energy solutions, free and economized cooling solutions and energy-saving air conditioner cooling solutions. For every solution, a definition, principles, features and application conditions are introduced.

Not every technology mentioned in this Technical Paper is suitable for all situations. When operators choose a solution, it should be selected according to specific local situations.

With the development of information and communication technologies and equipment, especially high-power density equipment, the communication industry's energy consumption is increasing. The communication industry must therefore be attentive to energy conservation and protection of the environment. These two issues are of great importance to every operator and effective measures are indeed being actively undertaken by operators all over the world. This paper can provide them with a Technical Paper on energy conservation solutions for power and cooling systems.

1.2 How to use the Technical Paper

This Technical Paper focuses on best practices for network infrastructure; however, energy-saving solutions should be selected according to local conditions such as year-round irradiance, wind speed, temperature conditions, humidity conditions, and communication room conditions.

2 Overview of ITU-T Technical Papers on Best Practices

In addition to the present Technical Paper on network infrastructure best practices, which is focused on solutions available to reduce the energy impact of networks (e.g. power converter solutions, alternative energy solutions (solar, wind, etc.), low-impact cooling solutions, etc.), there are currently other ITU-T documents dealing with Best Practices. For example, Recommendation ITU-T L.1300 on Green Data Centres describes Best Practices aimed at reducing the negative impact of Data Centres on the Climate Change. Moreover, there are currently under development further ITU-T Technical Papers dealing with Best Practices on innovative cooling solutions.

3 General requirements of network infrastructure best practices

3.1 General rules

Communication safety and equipment life cycle are the two basic conditions of energy-conservation activity. Therefore, any energy conversation activity that has a detrimental effect on safe operation and communication room environment is strictly forbidden.

3.2 General rules on the power-feeding system in telecommunications

General rules on power in telecommunications are as follows.

(1) The power distribution system should be optimized to reduce consumption through distribution loss.

(2) High efficiency power technology, such as high-frequency switching rectifiers sleeping technology and higher voltage power feeding system, should be actively used.

(3) Renewable energy such as solar systems and wind turbine systems should be actively used.

3.3 General rules of cooling in telecommunications

General rules of cooling in telecommunications are as follows.

(1) The temperature and humidity of the communication room should be reasonably set.

(2) Equipment lay-out in the communication room should be reasonably adjusted.

(3) Free and economized cooling methods such as outdoor air cooling systems and heat exchanging systems should be actively used.

(4) High-efficiency air conditioning systems should be selected.

4 High-efficiency power feeding solutions

This section covers solutions through high-frequency switching rectifier sleeping mode control, Up to 400VDC power supply, harmonic current elimination, modularized uninterruptible power supply (UPS) and magnetic-suspended free-wheeling energy storage systems.

4.1 High-frequency switching rectifier sleeping mode control

4.1.1 Definition

The high-frequency switching rectifier sleeping mode control serves to control the quantity of activated rectifiers in a power supply system by monitoring the load current to make the power supply system work around the maximum efficiency point.

4.1.2 Principles

Control of hibernation involves activation/deactivation of rectifiers. Redundant management rectifiers are controlled for cycling on/off via the controller.

In order to improve the efficiency of the power supply system, the controller shuts down some rectifiers to standby mode and makes the rest of the power modules work in the highest efficiency range by monitoring the load current. The controller will activate the standby rectifiers if the load current is increased.

To equalize the operating time of rectifiers and maximize the lifespan of a power supply system, the controller accumulates the operating time of each rectifier and periodically activates the standby rectifier with the lowest operating time. In parallel, the controller shuts down the operating power module with the highest operating time to standby mode. By following the above control rule, the operating time of power modules can be equalized and the lifespan of a power supply system can be extended as well.

4.1.3 Features

Characteristics of hibernation of high-frequency power supply systems are as follows.

(1) Always keep systems operating in the region around maximum efficiency point.

(2) Service time of power modules is extended.

(3) Aging of power modules is kept almost at a constant rate.

4.1.4 Application conditions

This technology is suitable for redundant modularized power supply systems.

Guidelines for application:

- Reliability and safety of a power supply system should not be downgraded while the hibernation function is enabled.
- If there is failure of the power module, the controller or the utility, or if equalization charge occurs in the power supply system, the hibernation function must be paused within the system. The sleeping function will be recovered if failure is recovered and the system is operating in the floating charge mode.

4.2 Up to 400VDC power feeding systems

This up to 400VDC power feeding solution is already described and defined in Recommendation ITU-T L.1200 and other Recommendations currently under development which cover other aspects on architectures and requirements.

4.3 Harmonic current elimination technology

4.3.1 Definition

Harmonic current elimination cancels high order harmonics in a power grid by active or passive technologies. The power quality, stability and power dissipation of the utility can thus be improved in order to protect users against the disadvantages of excess harmonics.

4.3.2 Principle

A passive power filter is sometimes also called a passive resonant power filter or L-C power filter. It consists of capacitors, inductors and resistors. A power filter for a certain order harmonic is designed on the basis of the frequency and amplitude of this harmonic. A power filter can only cancel a dedicated harmonic component.

An active power filter calculates the spectrum of the monitored load line current waveforms and creates other compensating currents with the same spectrum but 180 degrees phase shift for harmonic cancellation. The bandwidth of an active power filter can usually cover 2nd to 39th order harmonics. Some active power filters are also capable of improving the power factor.

4.3.3 Features

Characteristics of the passive power filter are simple, low-cost and widely used. However, it has heavy, bulky and limited-order harmonic cancellation disadvantages as well.

There are three types of passive power filters: series, parallel and low-pass filter types.

- The series type is suitable for 3rd harmonic cancellation.
- The low-pass type mainly focuses on high-order harmonics cancellation.
- The parallel type can filter out multiple harmonics and compensate reactive power at the same time. It is widely adopted for power quality improvement.

The active power filter is more complicated and expensive in comparison with the passive power filter. However, it shows better control performance, smaller size and adaptive tracking and compensation of different harmonic components.

There are four different types of active power filters: series type APF, parallel type APF, series hybrid type APF and parallel hybrid type APF. Hybrid type APF is a combination of passive and active power filter.

4.3.4 Application conditions

Conditions of application are listed below:

(1) Harmonic elimination is suggested if THDI of distribution network is over 10%.

(2) Passive power filter is suitable for the load which is steady and with fewer order harmonics.

(3) Active power filter is versatile and especially suitable for the station that is installed with high capacity UPSs.

(4) Guidelines for application:

- It is recommended to use parallel type APF. Parallel type passive power filter is also feasible for some stations for ROI considerations. For the harmonics coming from UPSs, close-loop, three-phase three-wire can be selected for local elimination and distributed elimination. For the harmonics coming from switching power supplies and air conditioners, close-loop, three-phase four-wire can be selected for local elimination and distributed elimination. For concentrated harmonics elimination in the low-voltage side of the distribution transformer, close-loop, three-phase four-wire is recommended.
- For a newly-built station, it is suggested that UPSs be installed with power filters and harmonic components elimination equipment to protect the power grid from harmonic current pollution.
- For low-voltage systems, a harmonic elimination solution according to the local condition is recommended. Spaces for active power filter, current transformers and termination must also be reserved.

4.4 Modular UPS

4.4.1 Definitions

Modular UPS consists of input distribution, output distribution, power modules and controller. Modules with the following characteristics:

- Mechanical with independent frame structure.
- Complete and independent functions.
- Coordinated operation between modules.

Power modules include rectification, inverting, charging(optional), power factor correction and corresponding control circuits. The power module is the key component of modular UPS. Under normal conditions, the modualized UPS must have the characteristics of hot-swap and redundance.

The controller is responsible for monitoring status, collecting data and operating parameters storage, event log and diagnostic of UPS.

4.4.2 Principle

Modular UPS consists of input distribution, output distribution, power modules, controller and so on. For “N+X” modularized UPS, N is the number of required power modules and X is the number of redundant power modules. Power modules are democratically synchronized and phase locked and are load sharing. If the number of failed power modules is less or equal to X, the system can maintain normal operation without any problem. In the event of a lack of controller or controller-

failed condition, the system should output rated voltage. While mains input is normal, power modules provide loads with stable, high quality AC power and battery charging. In the event of a mains failure, power modules invert the DC power from batteries to AC power and hence support the loads. Power modules should have the hot-swap function. Under normal condition and with sufficient redundant power, any one power module can be plugged out from the system without any influence on loads.

4.4.3 Features

Modularized UPS with the following characteristics:

(1) Usability

Modularized UPS has a failure isolation function for redundant design. In comparison with traditional UPS, the modularized UPS has features of easy replacement and shorter MTTR. Therefore, it demonstrates higher usability.

(2) Energy saving

Power modules with higher conversion efficiency for APFC and high frequency switching design.

Compare with the "1+1" redundant UPS, modularized UPS adopt "N+X" redundant design to ensure reliability. Conversion efficiency of the system is improved for high loading rate of power modules.

(3) Maintainability

Power modules use modular design to implement the hot-swap function. A maintenance engineer can replace a failed module anytime without causing any problem to normal system operation.

(4) Extensibility

A power module can be added to support the increased loads.

4.4.4 Application conditions

The number of redundant power modules can be determined by considering the reliability request and investment budget.

For (N + X) redundant UPS systems, any (1 ~ X) power module failed, other power modules can still work properly and output rated power of the UPS system.

For the reason that utility of most of the critical loads is double fed by a double power feeding system, it is recommended to use two modularized UPSs to constitute a double-bus distribution to support loads instead of to install two modularized UPSs in parallel.

5 Renewable energy power supply solutions

This section includes a solar power solution, wind power solution, wind-solar hybrid power solution, wind-solar-D.G power solution and a hydrogen fuel cell power supply solution.

5.1 The solar power feeding solution

5.1.1 Definition

The solar module will produce free charge by a specific semiconductor through solar radiation of light and heat. The solar modules then constitute the solar array which provides the energy of the load required.

5.1.2 Principle

Solar cells are devices which convert solar energy directly into electricity, either directly via the photovoltaic effect, or indirectly by first converting the solar energy to chemical energy.

The most common form of solar cells are based on the photovoltaic (PV) effect in which light falling on a two-layer semi-conductor device produces a PV or potential difference between the layers. This voltage is capable of driving a current through an external circuit and thereby producing useful work. The basic schematic of the solar cell is shown in Figure 1.

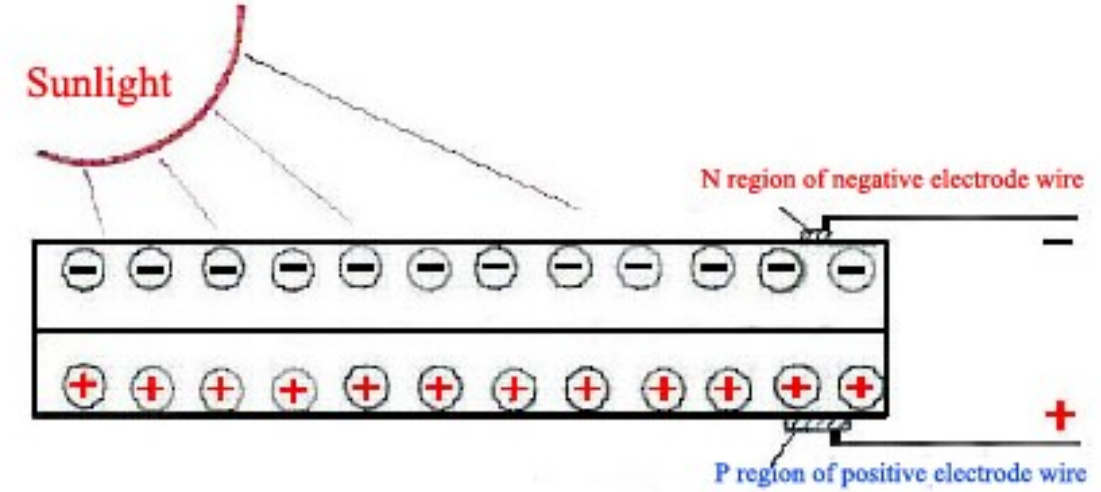

Figure 1 - The basic schematic of the solar cell

5.1.3 Features

Solar energy is a renewable energy. It has the following advantages:

(1) Without the cost of fuel. Solar energy is both a primary energy and a renewable energy. As it is rich in resources, we can use it free of charge, without transportation or any pollution to the environment. The theoretical calculation of the sun's lifetime is estimated at billions of years. PV systems do not require fuel, eliminating the cost of purchase, transportation and storage of fuel.

(2) No noise pollution. There are no moving parts in photovoltaic system and consequently the noise level is low.

5.1.4 Application conditions

1) the solar photovoltaic power feeding system for the annual average irradiance is sufficient.

2) the communication base station solar power system supply type includes the following mode.

(1) OFF-grid solar power system

The OFF-Grid solar system needs batteries as energy storage devices; the system structure is shown in Figure 2. It is mainly used for the grid in remote areas and regions of scattered population. As it is of high reliability, of low-cost maintenance and rich in resources, it is widely distributed in these areas.

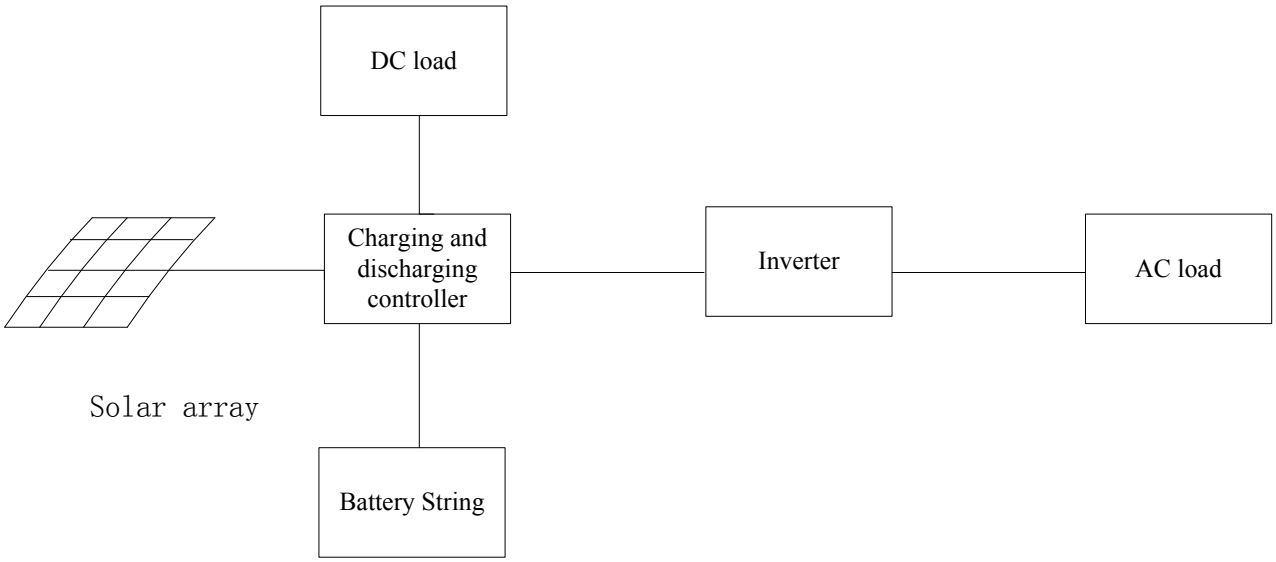

Figure 2 - OFF-grid solar power system block diagram

(2) Solar and diesel generator (DG) power system

In the solar and diesel generator (DG) power system shown in Figure 3, there is a standby DG (or mains) power lines in the system. When the PV arrays generate insufficient power or lack of battery capacity, the standby DG will start. It can be used to power the load directly to the AC load, but also charge the battery through a rectifier.

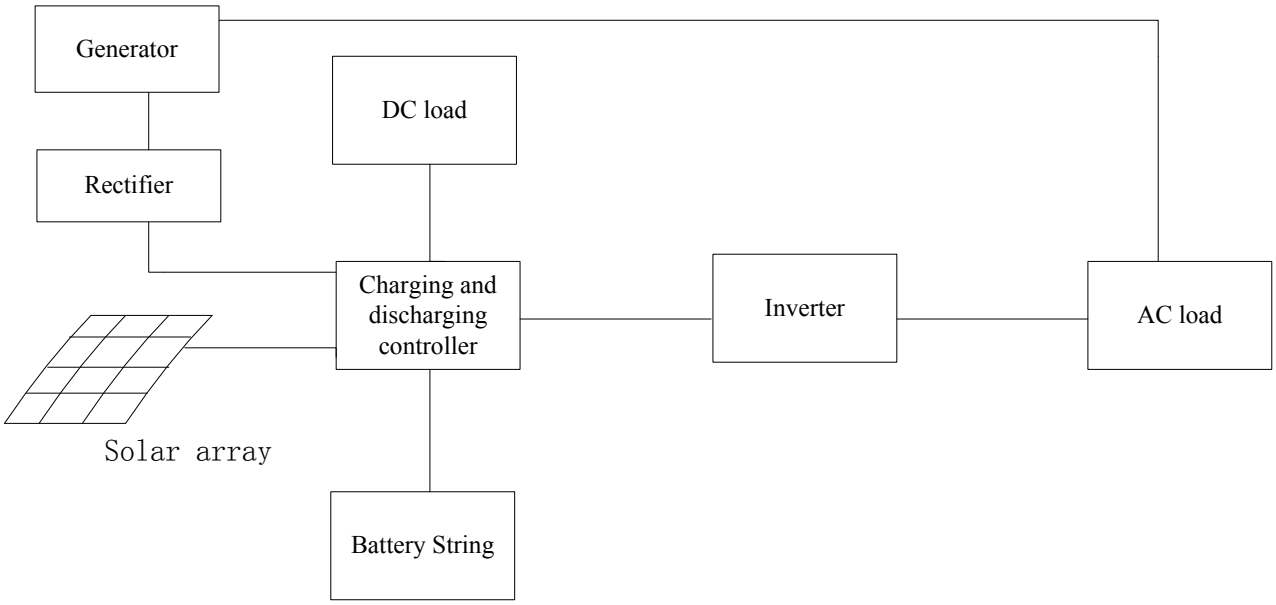

Figure 3 - Solar & D.G power system block diagram

3) Application note:

- Sunshine unstable. Sunshine intensity is affected by various factors (season, location, climate, etc.); as a result constant system energy cannot be maintained with the seasons.
- High initial investment. CAPEX of the solar power system are high
- Require energy storage devices. In order to ensure electricity during the night or when overcast and rainy, the solar power system needs to use battery energy storage; the battery increases the system cost and maintenance workload.

- Low efficiency of the system. The low energy conversion efficiency of solar cells, energy loss when the battery charges and discharges, and system transmission loss result in the overall efficiency of the solar power system not being high.

5.2 Wind power solution

5.2.1 Definition

Wind power technology transforms wind energy into electrical energy. The wind power system can be divided into the OFF-grid wind power systems and Grid-connected wind power system. The system for telecommunication base stations is the OFF-Grid system.

5.2.2 Principle

Wind power system structure is shown in Figure 4.

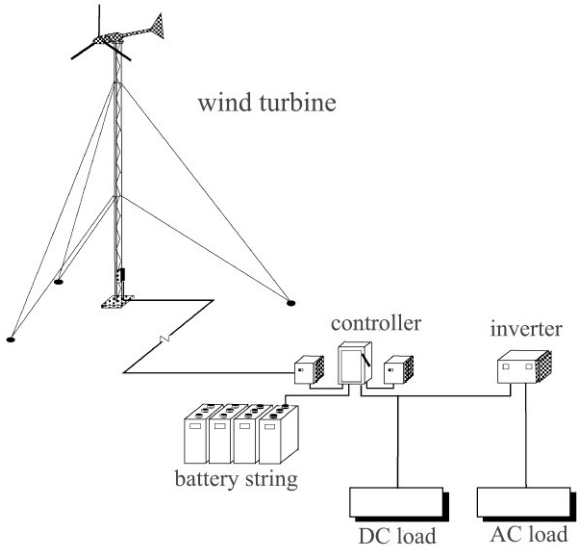

Figure 4 - Off grid wind power feeding system

1) Wind turbine: No-connection with the public grid, the wind generator system is therefore an independent system.

2) Energy-consuming load: It is for the excess power consumption when high winds.

3) Battery string: Battery bank stores electrical energy.

4) Controller: The system control unit, including the main function of the battery charge control and over-discharge protection, adjusting the system input, output power regulation, and distribution unit.

5) DC load: DC-powered devices or equipment.

6) AC load: AC-powered device or equipment.

By the wind turbine, wind energy is converted to mechanical energy, so as to drive the generator which converts mechanical energy to electrical energy. A rectifier will supply DC power to loads, or convert DC to AC output power to AC load. Considering the wind instability and to ensure the basic needs of the power supply should be based on load requirements to take the appropriate measures to achieve the balance between supply and demand.

Below 20kW wind turbine, the wind power system needs the battery string to storage energy.

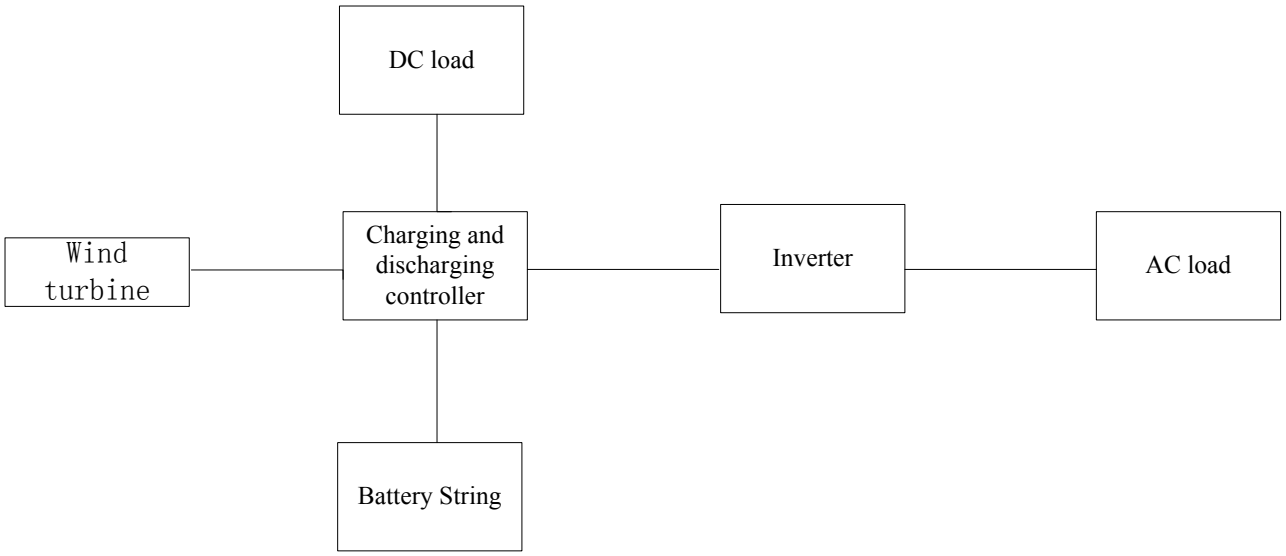

Figure 5 - OFF-Grid wind power system block diagram

A wind turbine system whose capacity is below 1kW does not have an accelerator; directly driven by the wind turbine generator, a low-speed permanent magnet alternator is commonly used; Wind turbine system whose capacity is more than 1kW are mostly equipped with a speed increaser, wing magnetic generators are commonly used, The rectifier directly powered DC load, and the excess energy charges the battery string. The inverter supplies AC power to load. The wind turbine is in variable-speed operation when wind speed is below the rated wind speed; otherwise the wind turbine works in the limited speed mode.

For larger wind turbine units (such as 20kW and above), the system requires a large capacity battery. Therefore, it needs high-price investment.

5.2.3 Features

(1) Wind power is a renewable energy source, it is inexhaustible and also a clean, natural energy.

(2) Wind power technology is increasingly mature, reliable and available. The economy of wind power is increasing, the cost of power generation close to that of coal and lower than that of gasoline-electric and nuclear power. Taking into consideration the coal-fired power environmental costs and transportation costs, the economics of wind power will be better than for coal-fired electricity.

(3) In view of the flexibility of the wind power system, construction, the time required for installation and construction is short.

(4) Non-centralized power grid. Small wind power system can reduce the effects and harm to the user in the event of a mains failure.

5.2.4 Application conditions

Conditions for application of power application are as follows:

(1) It is used in regions with sufficient wind energy resources;

(2) It is used in areas where there is a shortage of mains and where mains are unstable, such as remote mountainous areas and islands;

(3) The wind turbine system is used in communications base stations, access network and other occasions to save energy and to favour renewable energy.

Application note:

- Before the site design, the local wind resources should be collected and measured.
- In order to ensure the continuity and stability of the system power supply, wind power systems need to use the battery string to increase the system cost and maintenance workload.
- The efficiency of the wind turbine system is low as the battery charge and discharge energy loss are coupled with the system transmission loss.

5.3 Wind-solar hybrid power solution

5.3.1 Definition

Wind-solar hybrid technology is the power supply system with wind or solar technology for communication equipment using wind and solar power systems to complement each other to achieve a continuous and stable power supply.

5.3.2 Principle

Wind-solar hybrid power systems consist of wind turbines, solar array, the controller, the energy consumption load, battery string, inverter and the load, as shown in Figure 6.

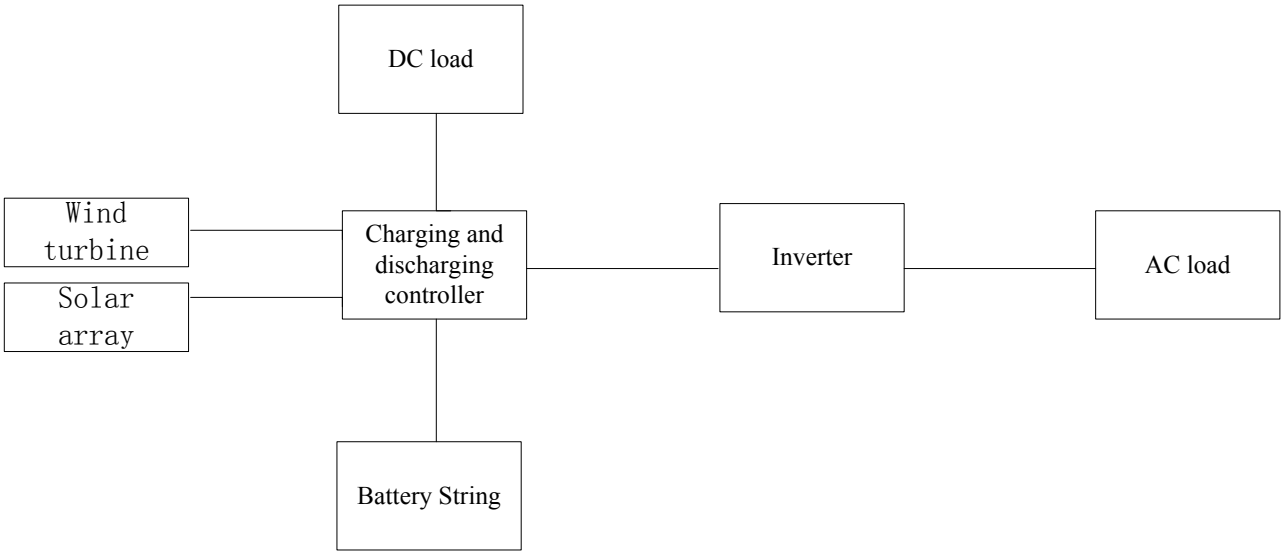

Figure 6 - Wind-solar – DG hybrid power system block diagram

Wind-solar hybrid power system includes the following main components:

1) Solar array: solar array can generate the voltage and current.

2) Wind turbine: wind turbine system can be run independently not to be connected with the public grid.

3) Load energy consumption: for excess power consumption when sustained wind power is exceeded.

4) Battery string: to store electrical energy devices.

5) Controller: It is the system control unit, including the main function of battery charge control and over-discharge protection, adjusting the system input, output power regulation, and distribution unit.

6) inverter: convert DC to AC power electronic devices.

7) DC load: DC-powered devices or equipment.

8) AC load: AC-powered device or equipment.

5.3.3 Features

(1) Using solar and wind power day and night power generation, communication power feeding system stability and reliability are improved.

(2) Initial investment is lower than the OFF-Grid solar power system. If solar and wind energy resources are complementary they can reduce the storage capacity of the battery string to ensure the same power supply.

5.3.4 Application conditions

(1) The wind and solar hybrid system is used in areas with sufficient wind energy resources and solar resources;

(2) It is used in areas where there is a lack of mains or the mains are unstable, such as in remote mountainous areas and islands;

(3) The wind and solar system is used in communications base stations, access network and other occasions for energy-saving and to use renewable energy..

Application note:

- Before the site design, the local wind resources and solar resources should be collected and measured.
- In order to ensure the continuity and stability of the system power supply, wind power systems need to use the battery string to increase the system cost and maintenance workload.
- The wind solar hybrid system design is more complex, and investment in the system is increased compared to the wind turbine system. Moreover maintenance work is increased.

5.4 Fuel cell power solution

5.4.1 Definition

In hydrogen fuel cells which store chemical energy, the fuel and oxidizer are directly converted to electricity. The hydrogen fuel cell electrode does not contain any active substance itself; it is only a converting part.

5.4.2 Principle

(1) A cell (take a proton exchange membrane hydrogen fuel cell as an example)

The proton exchange membrane hydrogen fuel cell uses hydrogen as fuel, air (oxygen) as the oxidizer, platinum / carbon or platinum - ruthenium / carbon as catalyst, perfluorinated or part of the fluorinated sulfonic acid solid polymer as electrolyte; its working principle is shown in Figure 8.

The hydrogen fuel cell working principle is the reverse process of electrolysis.

ANODE: $2H_2 \rightarrow 4H^+ + 4E^-$

CATHODE: $O_2 + 4H+ + 4E- \rightarrow 2H_2O$

The overall reaction: $2H_2 + O_2 \rightarrow 2H_2O$ + heat

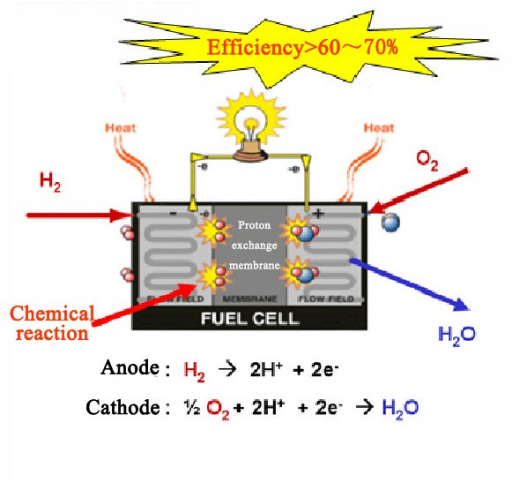

Figure 7 - The principle of the Fuel Cell system

When a hydrogen fuel cell works, the anode supplies fuel (hydrogen), the cathode supplies oxidant (air); hydrogen at the anode is decomposed into positive ions H + and e-, hydrogen ions enter the electrolyte migrate to the cathode, while electronics move along the external circuit toward the cathode. On the cathode, the oxygen in the air and hydrogen ions in the electrolyte absorb electronic combine to form water. In accordance with the definition of batteries, the fuel cell cathode within the external circuit is positive and the anode is negative.

(2) The cell stack

The hydrogen fuel cell operating voltage range is between 0.6V ~ 0.9V. In order to increase the output voltage, more than a single cell in series constitute the cell stack; the output voltage of the cell stack is equal to the single cell voltage multiplied by the number of cell in series. The output current is equal to the current density multiplied by its area. The cell stack assembly process is very strict; the seal is one of the key technologies of the assembly of the fuel cell, which aims to ensure that the gas in anode and cathode on both sides will not leak.

(3) The power generation system

Hydrogen fuel cells are the same as a traditional battery; they belong to the same electrochemical device. But there are differences - active substances such as fuel and oxidizer are all supplied from the external parts. When fuel and oxidizer from the external supply to the fuel cell are continually provided, it can continuously generate electricity, equivalent to an energy saving DC generator. The principle is shown in Figure 8. The fuel and oxidizer used are fluid, gas or liquid. The most commonly used fuel is pure hydrogen.

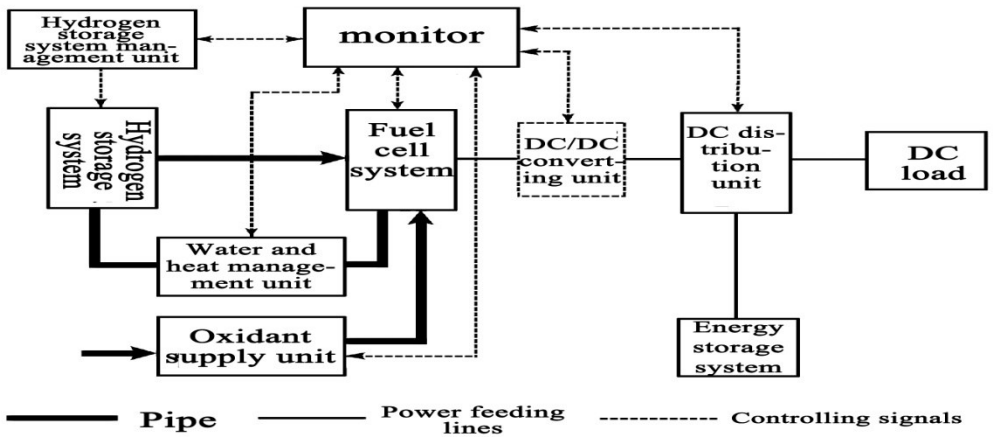

Figure 8 - Hydrogen fuel cell power system diagram

5.4.3 Features

The hydrogen fuel cell has the following advantages when compared to the traditional power system.

1) High energy conversion efficiency

A hydrogen fuel cell system converts chemical energy to electrical energy directly; in this way an excessive form of energy conversion and loss aspects can be avoided.

2) Environmentally friendly

Fuel cell hydrogen- the fuel cell has high energy conversion efficiency. The carbon dioxide emissions of heat are reduced by more than 40% and thus the hydrogen fuel cell has a positive impact on the greenhouse effect. When the fuel cell puts pure hydrogen as fuel, the chemical reaction product is only water; it virtually eliminates nitrogen oxides, sulphur oxides and carbon dioxide and other emissions; as there are no moving parts in the fuel cell power supply system, the noise of the system is quite low.

3) Superior performance

The fuel supply of the hydrogen fuel cell power system is sufficient; the system has high efficiency in the condition of light load or full load. Moreover, it has a strong overload ability. The hydrogen fuel cell power system has a characteristic of adaptability in high and low temperatures, long life, high reliability, and easy maintenance.

4) Flexibility

Arbitrary series, or a parallel combination of the system by the cell, can form a variety of capacities. System capacity is very flexible as cells connected in series or in parallel. It is very convenient to expand according to the customer's demand.

5) Fuel source

The source of hydrogen is extremely rich and hydrogen supply is a relatively mature industry.

5.4.4 Application condition

1) The fuel cell operating temperature:

Operating temperature

- Low temperature (below 100 ° C) fuel cells, including alkaline and proton exchange membrane fuel cell;

- Medium temperature fuel cell (working temperature 100 °C ~ 300 °C), it includes Bacon alkaline fuel cells and phosphoric acid fuel cell;
- High temperature fuel cells (operating temperature 600 °C ~ 1000 °C), it includes the molten carbonate fuel cells and solid oxide fuel cell.

2) The fuel cell system is not only suitable for centralized power generation but can also be used as a variety of decentralized power and mobile power.

The hydrogen fuel cell system used in communication base station belongs to a proton exchange membrane fuel cell system, and it has the characteristics of quick starting in room temperature condition, stability in output power, and environmental adaptability. It can also meet the needs of the communications industry; its structure is shown in Figure 9.

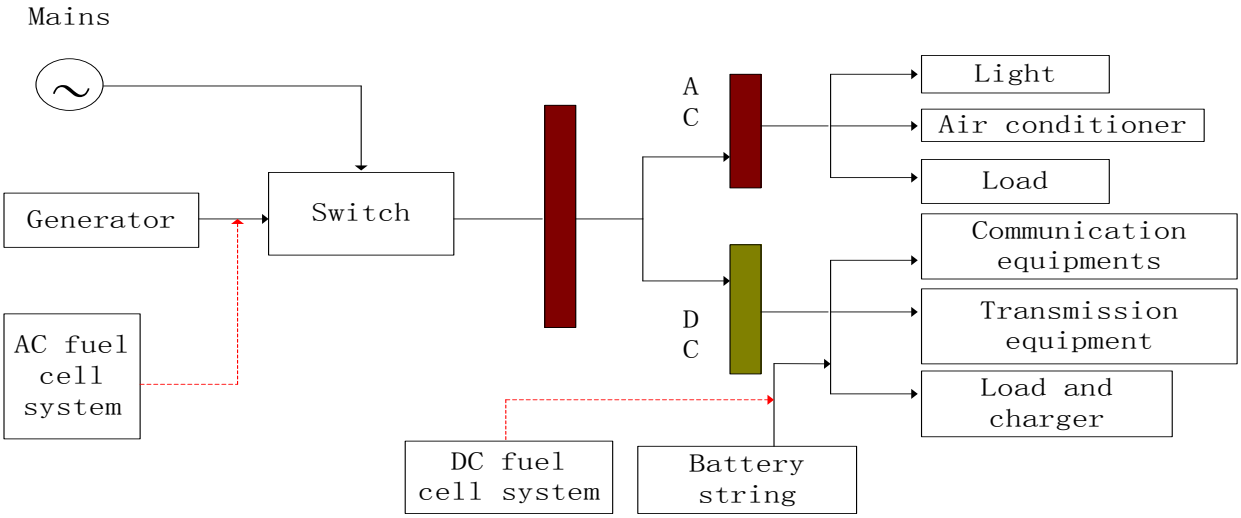

Figure 9 - Hydrogen fuel cell-powered system DC power supply and AC power lines

3) Application note:

- The fuel cell system should be installed outdoors at a distance of more than 3 metres from any building, and of more than 4.5 metres from sidewalks, roads, parking lots and populations. The cabinet foundation of the fuel cell should be good; the connection the system should be solid.
- Maintenance of the system focuses on leakage of hydrogen gas from bottle valves, fittings and pipes. Typically, it is recommended that the fuel cell power generation and hydrogen storage devices be installed with hydrogen detectors and a hydrogen concentration sensor. If there is hydrogen leakage in the system, the control circuit will close the valve to prevent hydrogen leakage.
- Periodic checks and replacement of the filter in the DC/DC converter and coolant liquid for the cooling system; it is also important to check water inside the fuel cell.
- Regular check of parts, pipes with or without corrosion, the connection loose, the hydrogen concentration sensor, the hydrogen pressure sensor, and the electromagnetic valve;
- Software needs to be updated every year.

6 Free and economized cooling solutions

This chapter includes an outdoor fresh air cooling solution, heat exchange cooling solution, heat pipe solution for energy conservation, phase change materials solution, underground room/cabinet power-saving solution, and so on.

6.1 Outdoor fresh air cooling solution

6.1.1 Definition

Intelligent outdoor fresh air technology is an air-conditioning system that uses intelligent controlling to purify and handle the air from outside, and then introduce it into the communication room in order to expel the hot air from the communication room. For that it does not use any refrigeration component but just uses the outdoor fresh air to realize the decreasing of the indoor temperature; thereby it can reduce power consumption in the station.

The outdoor fresh air water-wall-filter power saving technology makes use of the cool air outdoors during the seasons when the outdoor temperature is lower than the indoor air, like winter, spring and autumn. After filtering by the water-wall-filter, the cool air from outdoor can be cooled down by 4°C～10°C as well as being purified. The cool air can then be made to flow into the room by the draught fan so as to rapidly reduce the temperature in the room.

6.1.2 Principle

6.1.2.1 Intelligent fresh air technology principle

The outdoor air temperature and humidity conditions are detected by temperature and humidity sensors. When the temperature is lower than the set value, the fresh incoming door will be opened and the draught fan will be turned on in order to control the cool air outdoor flow into the communication room. The cool air will be exchanged with the hot air in the room and the temperature of the communication room can then be lowered. The outdoor cool air will be processed by the filter unit when it flows in, as showed by Figures 10 and 11.

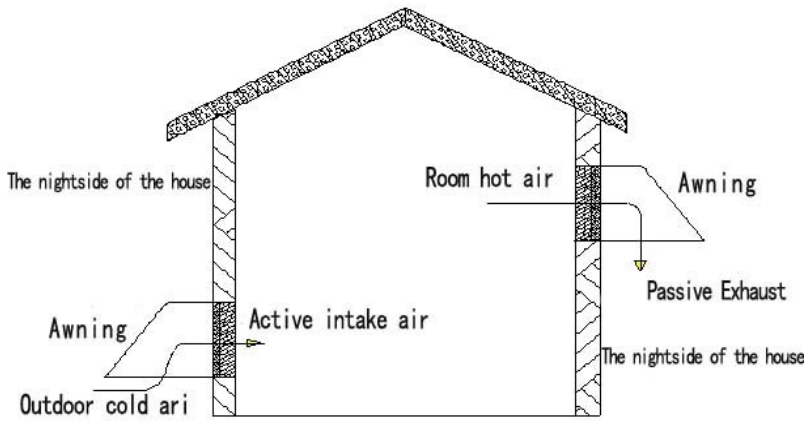

Figure 10 - Principle of fresh air system

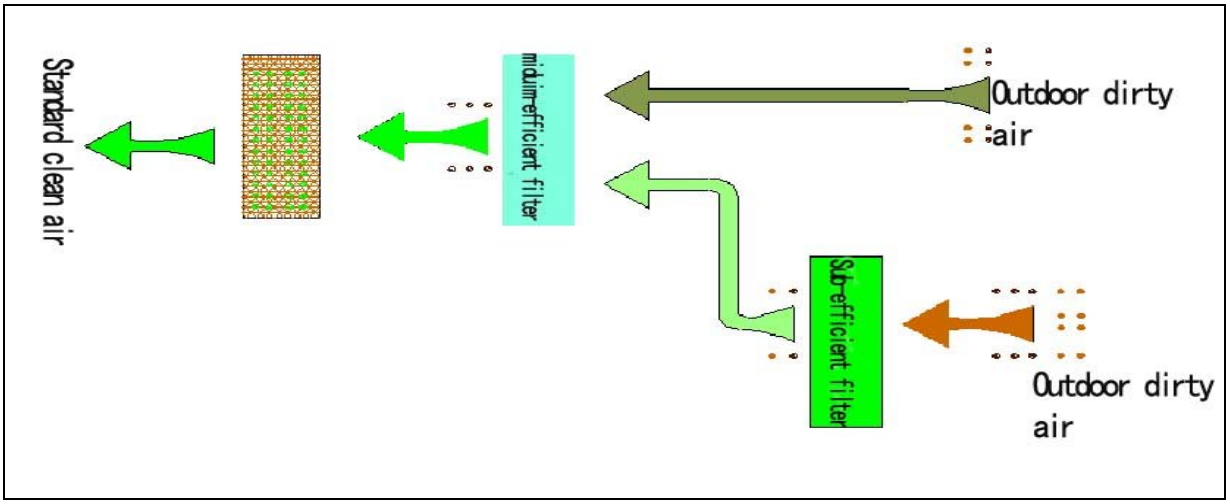

Figure 11 - Filter of the fresh air system

6.1.2.2 Principle of the outdoor fresh air water curtain filter system

The outdoor fresh air water wall filter system of the communication room consists of a power saving control module, temperature and humidity transmitter, inlet air equipment unit and air exhaust equipment unit. The power-saving control module, the temperature and humidity transmitter and the electronic control box constitute the temperature-humidity control system, which can be used to measure the temperature and humidity.

The power saving outdoor fresh air system consists of the inlet air equipment and the air exhaust equipment. It can introduce the outdoor cool air and reduce the air condition compressor boot time and electricity consuming.

The structure of the outdoor fresh air water wall system's fresh air filter is showed on Figure 12.

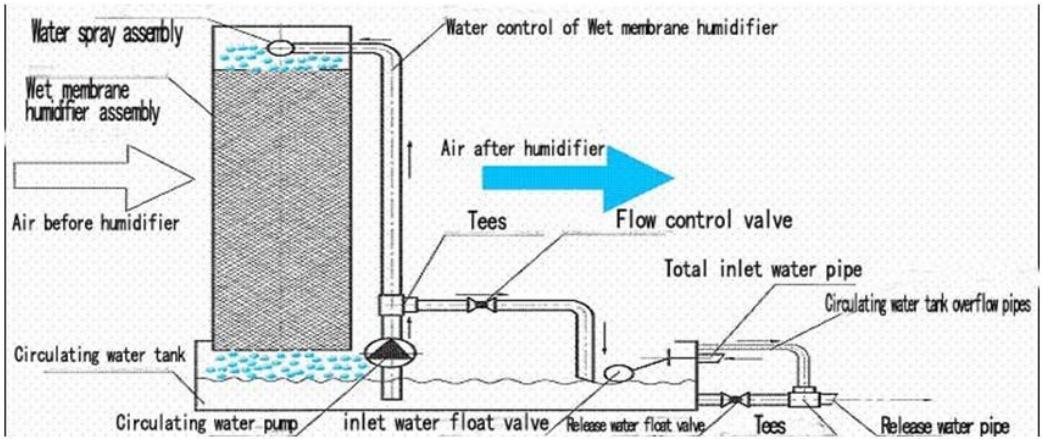

Figure 12 - Outdoor fresh air water curtain system structure

6.1.3 Features

Compared to other heat-exchange fresh air technology, outdoor fresh air technology can directly introduce fresh air in to the communication room, causing lower power loss. Though the power saving effect is obvious and the system is much more efficient, this method may have a bad effect on the environment. So relevant technology should be used to keep the required indoor temperature, humidity and cleanliness to ensure the communication equipment's' running.

Features of the outdoor fresh air water wall technical are as follows.

(1) Air filter: the inlet air machine uses a new kind of composite wet film which can continue to withstand a lot of water erosion so that dust and insects on the surface of the wet film can be washed away by the water.

(2) Equipment takes turns in working : when it is cold outdoors and there is no need to turn on all the air conditioners or draught fans, then equipment can be set to run in turns and save more power and prolong lifespan.

(3) Online function: each module has its own CPU which can run independently or can connect to the fresh air power supervision system by different methods (DCN、ADSL、PTSN、E1).

(4) Scalability: module reserved multiple analogue channels, switch channels and control channel. It can access other important data of the control room, such as monitoring the battery voltage, the state of the mains, etc.

6.1.4 Application conditions

6.1.4.1 The application conditions of the outdoor fresh air technoly are as follows.

(1) The outdoor fresh air system should be used in places where the nature cold air source is sufficient

(2) The temperature gap between different seasons or day and night is big.

(3) The outdoor air should be clean and the humidity should be balanced. The temperature gap between the outside and the indoors should be more than 10° C, and the relative humidity ≤90%.

(4) Before installing the fresh air power saving system in the access communication room, there should be an obligatory check of the room itself, the surrounding geography and environment and climate. These main issues should be considered:

- In the case of a communication room with a big power consuming access network, it is better to use this system;
- Appropriate selection for installation of an outdoor fresh air system;
- Forbidden to install the fresh air power saving system around dusty roads or a dusty factory;
- It is not suitable to install the fresh air power saving system in the high humidity environment;
- If humidity is very low, make sure the humidifier is used;
- If the temperature gap is too large, make sure that outdoor air and room air will be mixed.

(5) Before installing the fresh air power saving system into large communication room (IDC), there should be a necessary analysis of the room itself, the surrounding geography and environment and climate.

- Equipment in a large communication room has many strict requirements with regard to the environment. Such requirements need not only to meet the requirements on energy saving and quality of inlet air, but also those on harmful gas concentrations;
- In some areas, a humidity adjustment function is needed by the fresh air system. If the humidity of the cool air is too low, the humidification device will be used to improve the cold air humidity and to meet the humidity requirements of the engine room. When the power-saving outdoor fresh air system starts to work, any other air conditioning system in the room will stop.

Application guidelines

- The actual situation around should be considered when designing and choosing the fresh air system;
- Though the fresh air system can save power, installing it requires a certain input. Furthermore, using it may have some effect on the room environment and depending on changes in the environment in the control room; the filter net should be changed or cleaned periodically.
- The temperature and humidity acquisition sensor are the key components of the fresh air system. So the accuracy of these sensors should comply with relevant standards.
- According to changes of indoor and outdoor temperature, on/off status of the air-conditioning equipment and outdoor fresh air system should be changed. A delay time is necessary for preventing the air conditioner from starting and stopping rapidly.

6.1.4.2 The application conditions of fresh air water curtain technical are as follows.

(1) It is better to use this system in a communication room with big power consuming access network;

(2) Appropriate selection of the installation of an outdoor fresh air system;

(3) Forbidden to install the fresh air power saving system around dusty road or dusty factory;

(4) It is not suitable to install the fresh air power saving system in a high humidity environment;

(5) If the humidity level is low, make sure that the humidifier is used;

(6) Notes of application

- The indoor temperature and humidity transmitter should be installed in a place to collect the actual temperature and humidity of the entire room;
- The outdoor temperature and humidity transmitter should be installed in the same place as the inlet fan, and should not be exposed directly to the sunshine;
- The air inlet valve should be installed to prevent the hot air from flowing again into the room;
- The filter net should be checked and cleaned periodically;
- Based on the real-circuit distribution, select the appropriate location to install the temperature and humidity intelligent control system.

6.2 Heat exchange cooling solution

6.2.1 Definition

Outdoor fresh air is flowed into the room through the controlling unit; heat is exchanged in the hot air inside by the sensible heat exchange core module. As a result, hot air in the room will be exhausted. Without any refrigeration components, it can achieve the indoor air cooling and reduce the station's air conditioning power consumption.

6.2.2 Basic principle

One of the heat exchanger structures is shown in Figure 13. It is relatively simple and fresh air and room air do not come into contact with each other. For simple structure and lower cost, allow the heat exchanger to be widely accepted.

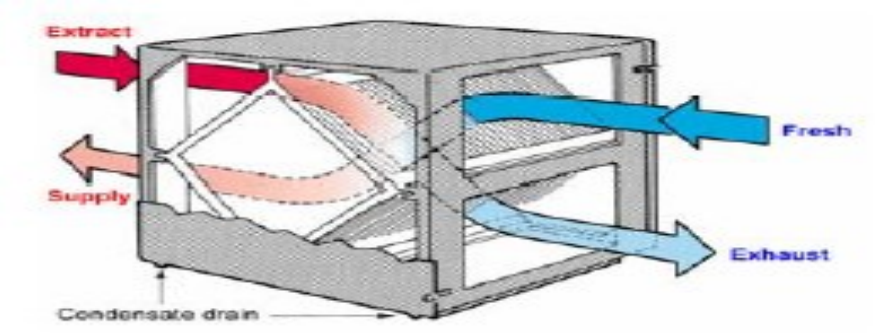

Figure 13 - Plate heat exchanger

Sensible heat transfer is used in this system. Using the temperature difference between indoors and outdoors to transfer heat, and eliminating the significant heat of the communications room when the outside temperature is low, it can partly or completely replace the computer room air conditioning equipment during winter or transition seasons to realize the power saving of the communication room air conditioning. According to the situation of the communication room, the heat exchanger can be placed inside or outside the room. The heat exchanger mainly consists of a heat exchanger core body, interior side draught fan, outside draught fan, ventilation ducts and a controlling system. Its structure is shown in Figure 14.

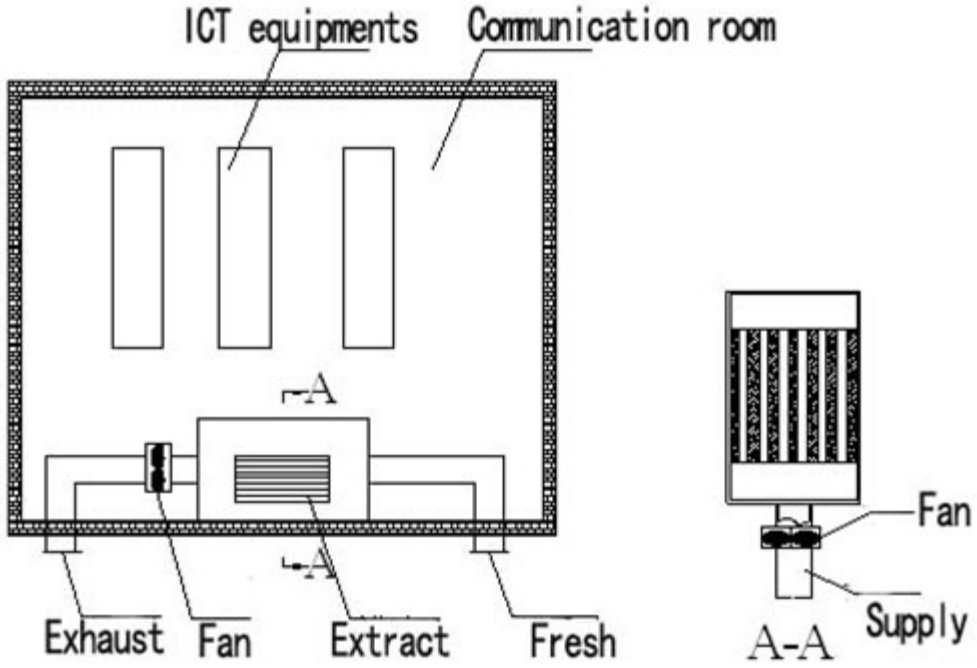

Figure 14 - Structure of plate heat exchanger

There are plenum chambers on two sides of the plate heat exchanger's air entrance to ensure the air coming from both side can come into complete contact with the heat-exchanger. The heat exchanging body inside has two independent air passageways. The heat exchanger is protected by the metal shell so as to be waterproof and anti-rust. The inner structure of the plate heat exchanger is shown in Figure 15.

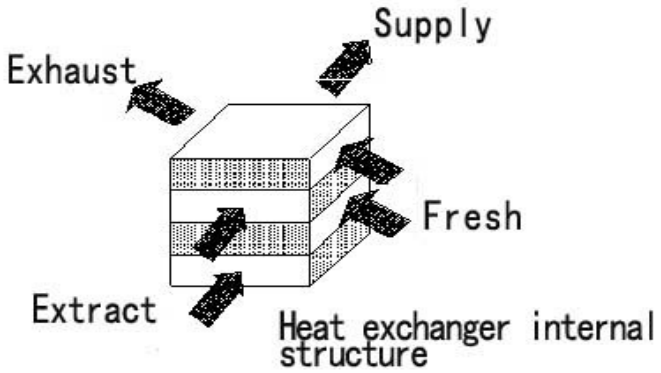

Figure 15 - Inner structure of plate heat exchanger

6.2.3 Features

(1) The outdoor and indoor air are isolated from each other to avoid outdoor air, indoor air pollution, so the cleanliness can be fully guaranteed.

(2) Easy operation and maintenance. Except for fans, there are no moving parts. The heat exchanger can be easily dismantled, cleaned and maintained and therefore effectively reduce operation and maintenance costs.

(3) Control and regulation is easy to implement. According to changes in the outdoor air temperature and load in the communication room, air volume should be controlled.

(4) Although sensible heat exchange will bring power loss, it still has a power-saving effect with higher efficiency than an air conditioner.

6.2.4 Application conditions

(1) This kind of technology should be applied in a place where there is sufficient natural cold air source. The air should be clean and humidity is balanced. The temperature gap between the outside and the indoors is more than 10°C.

(2) The requirements for the outdoor air are lower then for the outdoor fresh air system as it is not directly introducing system.

(3) Application notes：

- It should be reasonably determine the running or stopping of air conditioning equipment and heat exchanging system according to the indoor and outdoor temperature to avoid stopping and starting rapidly.
- The communications room power saving technological modification should combine with the original room air conditioning system. The modified ventilation mode should consider the original room air conditioning system structure to ensure the cooling effect.

6.3 Heat pipe solution for energy conservation

6.3.1 Definition

The heat pipe is the equipment in which the rapid heat transfer properties of the heat conduction principle are used; the heat of the hot side passes rapidly to the outside through the heat pipe.

6.3.2 Basic principle

The heat pipe is a heat transfer component that has high thermal conductivity, the heat will be transferred by refrigerant evaporation and condensation in an enclosed vacuum shell. The heat pipe

heat exchanger has many advantages like high heat transfer efficiency, compact structure, small fluid resistance loss, and an easy-to-control-the-dew point etc. The heat pipe heat exchanger consists of evaporators, condensers, fans and other components. The evaporator is filled with circulating refrigerant which is connected to the evaporator and condenser through the pipe. When fans start to drive hot air into the control room flows through the evaporator, the circulating refrigerant inside the evaporator transforms to gas, and passes through the main air pipe then comes to the condenser. Gas in the condenser becomes liquid when the outdoor cool air passes through the condenser, then returns to the evaporator through the main liquid pipe. This technology can avoid the security risks that are directly caused by the introduction of outdoor polluted air. Moreover, high efficiency of heat transfer can be achieved from the communications room.

The working principle is shown in Figure 16.

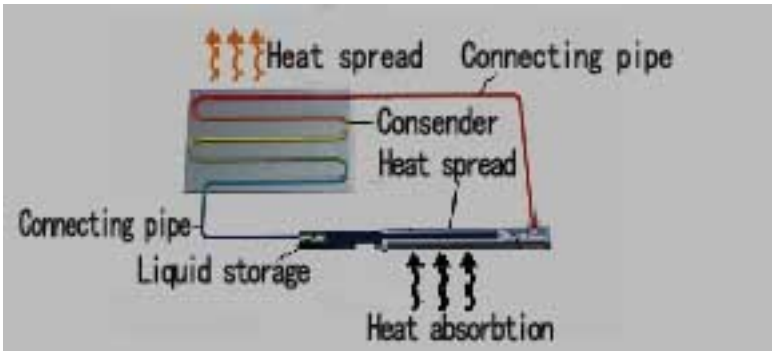

Figure16 - The basic principle of heat pipe

6.3.3 Features of the system

1) It does not have high energy-consuming components (such as: compressors).

2) It has high operational stability, reliability, security

3) Heat transfer at both ends can work independently, so it can effectively protect the cleanliness of indoor air and maintain humidity. No polluted air is generated by the running of the system.

4) The volume of the devices is small and therefore easy to install and maintain.

5) It works in parallel with the original air conditioning system at high temperature ranges. The alternation of the two equipment operation can be mutual backup. Not only can it save energy, but also be very effective in protecting safety and reliability, to extend the life of the air-conditioning equipment.

6.3.4 Application conditions

1) This technology is suitable for a base station or communication room with small heat generation;

2) It can be applied in a variety of building structure types, brick, coloured steel, and houses.

3) It is applicable in a region where the temperature is below 15° C.for most of the year

6.4 Phase change material technology

6.4.1 Definition

Phase change material (PCM) has the ability to change its physical state in a certain temperature range. For example, the solid-liquid phase transition produced the phase change from solid-liquid when heated to the melting temperature. When melting, phase change materials absorb and store large amounts of latent heat. As the phase change material cools down, and the stored heat is distributed to the environment when a certain temperature range is reached, then the PCM inverts

from the liquid-solid phase change to the solid-liquid phase change. During the phase transition, storage or release of energy is known as latent heat, which has a wide range of commercial applications. Ice is a common phase change material, which absorbs or releases large amounts of energy when the temperature of the solution temperature is 0°C .

Each phase change material model and its latent heat solution temperature parameters can be seen in Table 1.

Table 1 - Phase change material model and its latent heat solution temperature parameters

Product type	Melting point of the latent heat kJ/kg	Temperature range° C	Maximum latent heat kJ/kg
PC29	188	24～34	200
PC24	158	20～26	170
PC17	175	14～20	180
PC7	189	3～9	205

6.4.2 Basic principle

In view of its energy-storage characteristics, PCM has great application value at ambient temperature control in building energy efficiency, modern agriculture greenhouses, and so on.

The principle of the PCM outdoor cabinet: Install a certain amount of phase change materials in the outdoor cabinet. When phase transition occurs, the absorption characteristics of the latent heat of phase change material can be used. The corresponding monitoring device will control the internal temperature of the cabinet. Upon detecting that the outside temperature of the cabinet is low (lower than the phase-changing temperature but still within the normal working temperature range of the cabinet), the ventilating control system introduces the outside cold air into the cabinet in order to cool down the cabinet and also stores the cold energy into the PCM ; Upon detecting that the outside temperature of the cabinet is high (higher than the phase-changing temperature), the ventilating control system stops working and, in order to achieve the purpose of cooling through the phase change materials, absorbs the heat of the equipment.

The principle of the PCM energy storage air-conditioner: It takes advantage of the temperature difference between day and night as the cold source in the natural environment and the latent heat of phase change materials. When the temperature is low (for example, in winter), use the heat exchange function of the phase change thermal energy storage air-conditioner to bring low temperature outdoor air to decrease the communication room. When the temperature is moderate (for example, spring and autumn), when the temperature is low, cool down the communications room, at the same time use the energy storing feature of PCM to save cold energy; if the temperature is high, release the cold energy to lower the indoor temperature. This kind of air conditioner can avoid the power loss of start and stop, so it can prolong the equipment's life and greatly improve energy efficiency.

6.4.3 Features

(1) Features of PCM

- Stability: After variety of phase change cycle, long-term stability has been confirmed.
- Package: Phase change material encapsulated in a high-strength polyethylene shell can be adapted to any geometry of application requirements.
- Security: The phase change material is a mixture of inorganic substances and thickeners. The detection of relevant departments shows that it will not cause any harmful effects on the surrounding environment.
- Green: PCM is non-toxic, non-polluting, and non-flammable. It can provide new solutions for the temperature environment of the outdoor equipment, and outdoor cabinets do not need to be maintained.

(2) Features of PCM outdoor cabinet

Using the energy storage characteristics of PCM, and the natural cold source of the temperature gap between day and night, the PCM outdoor cabinet can save energy. It can save more than 90% of energy when compared with traditional cooling methods. It uses a quick plug cold bridge structure which gives the cabinet excellent insulation properties, and the integrated heat transfer coefficient is less than 1.2W / (m² K). Its double-layer radiation "o" structure perfectly combines the heat exchanging passage and the insulation. When the power is off and the outdoor temperature is 40^{o}C, the inside temperature can maintain a temperature below 32^{o}C for 8 hours. It only needs one hour to build and the price is much cheaper than the traditional air conditioner.

(3) PCM energy storage air-conditioner

The natural cold source is used and stored in this system, so it requires a temperature gap between inside and outside. The heat exchange equipment requires a temperature gap of only 8^{o}C, so it can prolong the time that equipment can use an outdoor cold source. Inside and outside are absolutely isolated, so it can prevent dust and humidity from coming in. Installation is very easy, just like installation of an air conditioners Moreover, it is effective in reducing the number of starts and the run-time of the compressor. Therefore it can extend the service life of the main air-conditioning equipment, compressors, and improve overall system reliability. It can save 40% to 60% energy when compared to the traditional air conditioner.

6.4.4 Application conditions

(1) PCM outdoor cabinet

Best running environment temperature of PC29 is that the average day and night temperature is 29±2oC; continuous maximum temperature is not greater than 38oC, the day and night temperature gap is greater than 12oC, and temperature remains above 29oC for no more than 12h per day.

(2) Phase change thermal energy storage air conditioning

- It can be used in the place where the natural cold air source is sufficient. The temperature gap between the outside and the indoors should be more than 10°C;
- It is applied mainly by base stations and other small communications station.
- It can partly be applied in regions where summer is hot and winter is cold.

6.5 Underground communication room/cabinet power saving solution

6.5.1 Definition

The term 'underground communication room' means that the whole base station is under ground and there is just an entrance for construction and maintenance. The whole room is made of brick and concrete materials or is an airtight metal box so that an anti-water, dehumidifying characteristic is necessary.

The term ‘underground cabinet’ means that the whole cabinet is under ground and the earth can absorb the heat generated by the cabinet or provide an insulation environment. It is applied as power supply cabinets, battery cabinets, etc.

6.5.2 Basic principle

The underground temperature can be divided into three layers

- the first layer is called the outer thermal layer (temperature layer), the surface temperature of which is mainly from the heat of the sun's radiation, and changes with the degree of latitude, land and sea distribution, season, day and night, and vegetation cover
- the second layer is called the constant temperature layer (heated floor), the lower interface of an outer thermal layer, the underground temperature remained constant temperature
- the third layer is called the heat layer (bystratosphere), the layer is free from the influence of solar radiation, the heat from Earth's interior.

Set the underground room/cabinet into the temperature layer or the heated floor, and use the balance of the underground temperature to maintain the temperature balance in the communication room, to reduce the impact of the outdoor natural environment or the temperature inside the room so as to reduce the power consumption of air conditioning, so as to achieve power saving.

6.5.3 Features

1) Power saving. As the room is located in the ground, it is less affected by the external environment, so there is no need to install air conditioning in the communication room.

2) Space saving. It is underground.

3) Safeguarding the investment. The communication room is in the underground heated layer, or in the temperature layer, and the effect of the outside temperature is very small; consequently air conditioning is not necessary and investment in air-conditioning equipment is not required

4) Anti-theft security. Avoiding theft since the room is located in the ground.

6.5.4 Application conditions

1) Climatic conditions

The surface temperature for the underground should not be too high.

2) The materials of the underground room.

A sealed metal box or brick,concrete constructed materials canbe used. In order to ensure manufacturing quality and reliable, waterproof seal, a high strength, metal box structure is recommended.

3) Water proofing

The nderground room should be fully enclosed.

4) Notice

Soil thermal conductivity has a great effect on the underground base station when installing the underground room so soil quality and water content should be considered.

7 Air-conditioning power-saving solutions

The following clauses cover the glycol power-saving solution; refrigerant pumping power-saving solution; adaptive control of air conditioning power-saving solution; aerosol spray and condensation water recycling solution of air conditioner outdoor unit; frequency conversion solution of central air conditioning system; and a fresh outdoor air and air conditioning integration power-saving solution.

7.1 Glycol power-saving solution

7.1.1 Definition

The glycol power-saving solution is a technology using the indoor and outdoor temperature gap and an ethylene glycol solution as a refrigerant to realize the heat exchange between indoor and outdoor air.

7.1.2 Basic principle

The system structure is shown in Figure 17. It is using the glycol power-saving system when the outdoor temperature is low. As the water pump is running, the glycol brings indoor heat to the outdoor condenser which dismisses the heat. When the glycol power-saving system is working, the air conditioner compressor can be stopped. As the power consumption of the water pump is much smaller than the compressor, energy will be saved. In the meantime, the indoor air and outdoor air will not be mixed, ensuring that the indoor air is clean.

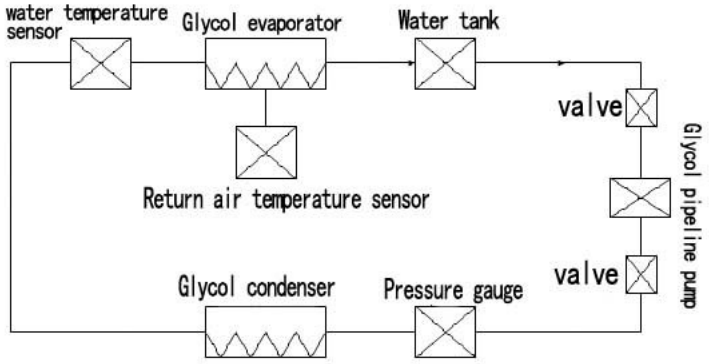

Figure17 - Glycol evaporator system structure

7.1.3 Features

(1) The glycol power-saving system can work independently or work with air conditioner to consist double cold source system. When it is working, the air conditioner compressor stops and only the indoor fan is working, so it can reduce the power consumption of the air conditioner compressor.

(2) The glycol unit has a reliable independent industrial control unit, so that the glycol unit is stable, with high control precision, and does not affect the normal work of the original air-conditioning system.

(3) When modifying the glycol power-saving system, it is not necessary to change the structure of the air conditioner. The existing air conditioner system will therefore not be affected and the structure of the room will not be destroyed.

7.1.4 Application conditions

1) The temperature gap between the outdoor and the set temperature should be larger than 10^{o}C ;

2) Notices:

- The glycol power-saving system uses the PPR pipe, so there is not any internal corrosion or external oxidation and no need for pipe maintenance
- Because the closed electromagnetic pump will not leak, it is better to use this kind of pipe in a water pump of the glycol system.
- A little glycol and water should be added to the system every year.

7.2 Refrigerant pumping power-saving solution

7.2.1 Definition

The refrigerant pumping power-saving technology is used in the season when there is big gap between indoor and outdoor temperatures. If the outside temperature is low, the system uses the evaporator of the refrigeration system and the air-cooling condenser automatically switches to the refrigerant pump refrigeration. For that refrigerant pumping, consumption power is much smaller than the compressor power and the communication room can be rapidly cooled as well to achieve energy saving objectives.

7.2.2 Principle

The refrigerant pumping power-saving equipment is made up of a refrigerant pump, control module, temperature sensor and the liquid receiver.

In summer, air-cooled air conditioners start normal refrigeration compressor refrigeration. When the outdoor temperature falls below the set value, the control module will send commands to stop the refrigeration compressor and start refrigerant pump cooling. The evaporator then absorbs heat and the vaporized refrigerant comes into the outside room air-cooled condenser. After heat exchanging with outdoor cool air, it becomes liquid, overcoming the system resistance and being delivered to the evaporator by the refrigerant pump power-saving module. It then absorbs heat in the room to decrease the temperature as well as save power. Figure 18 shows the process of refrigerant pump circulation.

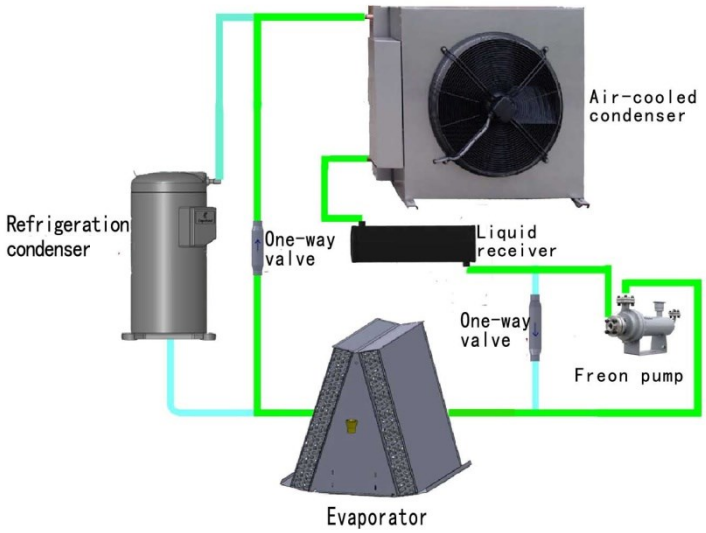

Figure 18 - Refrigerant pump power-saving technology

7.2.3 Features

1) Indirect use of the natural source of cold air quality and no environmental impact on the communication room.

2) Uses the outdoor nature cold source when the pump is cycling, so no need to start the compressor. That is to say, the compressor working time can be reduced by more than one-third which prolongs its lifespan.

3) The system functions without adding antifreeze, thereby reducing maintenance work. As there is no need to worry about water leakage, the reliability of the control room has been improved.

4) The energy efficiency ratio of the air-cooled computer room versus the air conditioner is generally between 2.5 to 3.0, but the efficiency ratio of the refrigerant pump power-saving system can reach 9.5 when the outside temperature is -10° C. The power saving is obvious: when the outdoor temperature is much lower, the energy efficiency is higher. The test parameters of the refrigerant pump power-saving system are shown is Table 2.

Table 2 - Refrigerant pump power-saving system testing data

Cooling capacity working conditions	Room condition	Dry bulb temperature 24.10°C Wet bulb temperature 17.13°C	Dry bulb temperature 24.05°C Wet bulb temperature 17.04°C	Dry bulb temperature 24.04°C Wet bulb temperature 17.04°C
	Outdoor condition	0.10°C	-5.10°C	-9.57°C
Air conditioning air flow (m3/h）		7.481	7.467	7.387
Cooling Capacity Q0 (kW）		20.253	25.631	30.676
Power W（kW）		3.328	3.345	3,330
Energy efficiency EER (W/W）		6.086	7.662	9.212

7.2.4 Application conditions

1) The period when the average temperature is below 5°C should be more than one-third of the year.

2) It should work as a complement to the air-cooled air conditioning system.

7.3 Adaptive control of air conditioning power-saving solution

7.3.1 Definition

The adaptive control of air conditioning power-saving technology is a power-saving system that uses a self-adaptive control method to supervise and automatically adjust the output air flow and temperature of the air conditioner; therefore several air conditioners can be working in a coordinated way.

An air conditioner should be adaptively controlled according to different areas of the room, changes in the day and night temperature and humidity , different seasons, and different regions. An air conditioner can automatically adjust its working status and temperature to coordinate with other air conditioners. thus saving energy.

7.3.2 Basic principle

(1) Fuzzy control technology: automatic tracking changes of day and night, seasons, areas, communication room temperature and humidity values. The surface of the communications room and the external environmental temperature and humidity values are accurately caculated.

(2) Use PID technology:

1) Dynamically adjusts the air conditioning temperature, humidity, corrects values and other parameters.

2) PID (P: Proportional control; I: Integral control; D: Differential control) technology: an intelligent control method can adjust automatically according to working parameters, environment and changes in raw material costs, to achieve the best status for the system all the time.

3) Computer temperature simulation technology: Depending on the communication room's different working conditions, the cold air volume and other comprehensive data , efficiency can be improved and the cooling capacity can be optimized. In order to achieve maximum efficiency of the cooling capacity, priority should be given to air conditioning. To achieve the best status, the "N+1", "N", "N-1" and number of air conditioners should be precisely controlled. Then a constant temperature and humidity level is achieved in the communication room, the communication environment safety is improved, and power consumption is reduced.

7.3.3 Features

(1) Through appropriate control, the total cooling output of the air-conditioner can reduce the compressor working hours and save the power consumption of the air-conditioning system.

(2) Automatically traces the temperature and humidity to allow the humidification and dehumudification working status to be appropriately controlled and reduce the working time of the compressor.

(3) Changes the independent working status of air conditioners to coordinated mode.

7.3.4 Application conditions

(1) This kind of technology is applied in places where cold energy is seriously insufficient.

(2) A large number of cables seriously clog the air conditioning outlet.

7.4 Aerosol spray and condensation water recycling solution of air conditioner outdoor unit

7.4.1 Definition

The aerosol spray and condensation water recycling technology of the air conditioner outdoor unit provide aerosol water to the outdoor unit of air conditioner to improve the heat exchange efficiency of the condenser. The system recycles the condensation water and sends it to the aerosol spray.

7.4.2 Basic principle

The outdoor unit the system can be divided into an aerosol spray part and condensation water recycling part due to the different function.

1) Principle of aerosol spray

The water drop is atomized by the high-speed DC motor - the structure can be seen in Figure 19. It will then be sprayed into the air conditioning outdoor condenser to absorb heat.

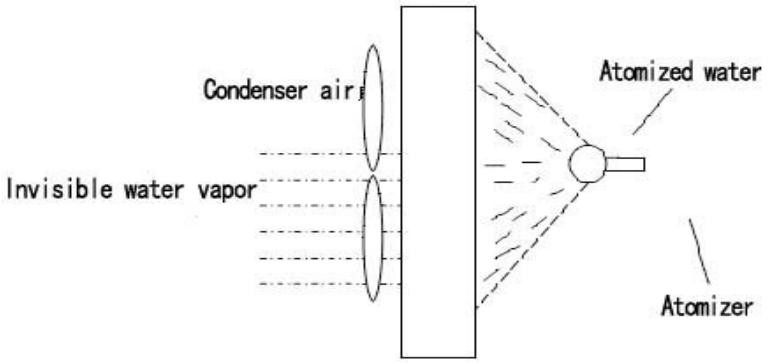

Figure 19 - Atomizing spray

2) Principle of condensation water recycling

Recycling the condensation water and providing the aerosol spray with it to achieve a benign cycle as well as to restore water and electricity, the structure is as shown in Figure 20. If the recycled water is not enough for the aerosol spray, tap water can be used as supplementary water.

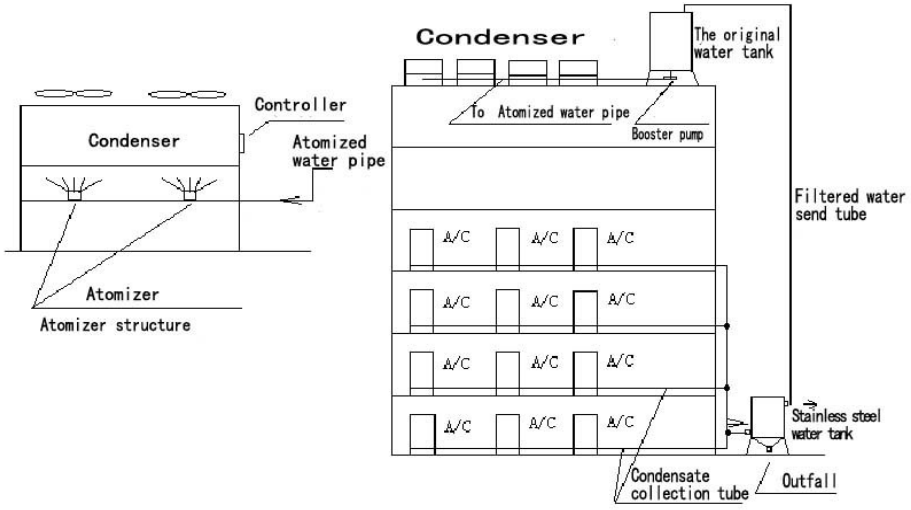

Figure 20 - Principle of condensation water recycling

7.4.3 Features

(1) After spraying, condenser cleanliness has been greatly improved. Aluminium fin is no longer dusty and the cooling effect has been improved.

(2) Collecting the condensation water generated by the air conditioner and providing it to the aerosol spray can achieve the water and electricity saving objective.

7.4.4 Application conditions

The application conditions of the air conditioner outdoor unit aerosol spray and condensation water recycling technology are as follows.

(1) There should be a sufficient water source. The source can be tap water which can fulfil the system requirement . If the water is too hard, tap water should first be softened by a water softener. The water pressure should not be lower than 2bar, otherwise a pump should be used.

(2) Any air-cooled air-conditioning can have this device installed. But nowadays the aerosol spray power saving equipments are mainly for large air conditioners just like communication room air conditioners, indusrial air conditioning systems and large cabinets.

(3) Notices

- The atomization of water is directly related to the motor speed, working conditions and the amount of water spray.
- A filter should be set between the water box and the pump to prevent the solenoid valve and control valve from being blocked.
- The water should be drained when a cold winter arrives.
- When recycling the condensation water, remove calcium and magnesium ions and other impurities to soften hard water.

7.5 Frequency conversion technology of central air conditioning system

7.5.1 Definition

Frequency conversion technology of a central air conditioning system is a technology that controls the inverter speed, fan and condenser.

7.5.2 Basic principle

1) The principle of the inverter

The principle of the inverter is simple. Firstly, the inverter transfers the AC electricity into DC, and then inverts it into AC of another frequency and voltage.

The three-phase power supply has been rectified into DC. The capacitor in the DC circuit can reduce the voltage fluctuations, and can provide power for shortly power failure. The DC voltage is inverted into AC by the PWM technical. The ideal wave can be established by the switching of the IGBT at a fixed frequency. Changing the IGBT switch time can obtain an ideal current. The motor induction can turn it to sinusoidal motor current.

2) Typical connection of the inverter

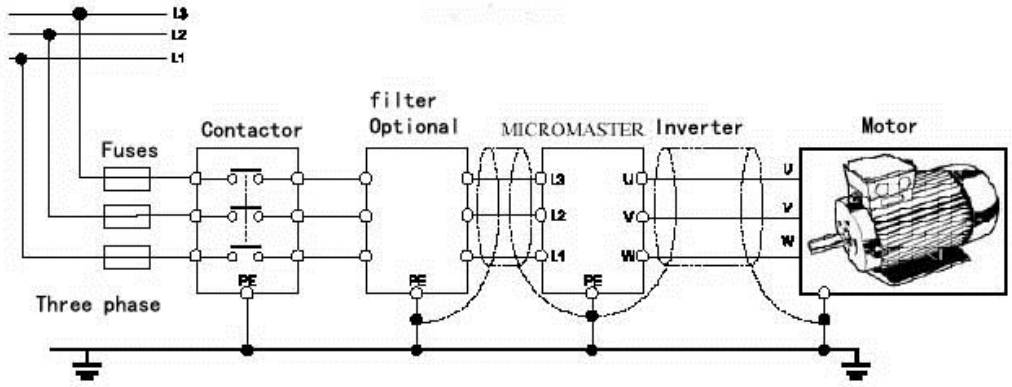

Figure 21 - Inverter connecting way

(3)The principle of frequency conversion

The traditional speed controlling method for a fan and water pump is to control the valve opening. Lots of power has been lost during this procedure on the valve. When using frequency conversion to change the pump speed, the power consuming is obviously reduced.

The relationship among the pump flow, head, shaft power and rotate speed is shown by the formula (1).

$$\frac{G_1}{G_2} = \frac{n_1}{n_2} \quad \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2 \quad \frac{N_1}{N_2} = \left(\frac{n_1}{n_2}\right)^3 \qquad \text{……(1)}$$

In the formula,

- n1，n2：motor rotate speed；
- G1，G2：water flow；
- H1，H2：pump head；
- N1，N2：Pump shaft power；

7.5.3 Features

According to the mechanical characteristic, the inverter can be divided into constant torque load, constant power load and the fan, water pump load. The features are as follows.

(1) Constant torque load

The load torque TL has no relation with rotate speed n for this kind of load. Whatever the speed is, the TL is or almost is constant.

(2) Constant power load

The power is constant whatever the speed is. When the speed is low, with the limitation of the mechanical strength, the TL cannot increase to infinite. So in a low-speed condition, it is the same as a constant torque load.

(3) Draught fan, water pump load

For all kinds of fans, pumps, fuel pumps, air or liquid, the resistance is proportional to the square root of speed n. When speed slows down, the torque reduces two-fold. Power and speed have a cubic relationship. When the requirement of air volume and water flow becomes small, the frequency converter technology should be used to control them, thereby saving a great deal of power.

7.5.4 Application conditions

1) Frequency converter technology should be chosen according to the load type. Central air conditioning chilled water pumps and cooling water pumps belong to the type of fan and pump load, so this kind of technology can be used.

2) As output of the inverter contains high-order harmonic, it will decrease the power factor and efficiency. Considering this, there should be little margin to the power of the motor, to avoid reaching the high temperature.

3) Some special environments will reduce the frequency converter capacity, e.g. high temperature, high frequency switching and high elevation. In these conditions, the larger capacity converter should be chosen.

4) The class of safety protection should match the environment. If not, the dust and humidity will impact the frequency converter.

7.6 Fresh outdoor air and air conditioning integration power saving solution

7.6.1 Definition

This technology is a combination of air-conditioning technology and outdoor fresh air cooling which uses filtered outdoor fresh air to cool the control room when the outside is cold.

7.6.2 Basic principle

The system has two working mode due to the outside temperature. One is a mechanical cooling mode and the other is a natural cooling mode. When the temperature outside fulfills the natural cooling mode, the cool air outside can be used to cool the room directly (outdoor fresh air system works). When the temperature outside cannot fulfill the natural cooling mode requirerments, the mechanical cooling mode (air conditioner works) should be used.

7.6.3 Features

The efficiency of the natural cooling mode is high.

7.6.4 Application conditions

1) The system should work in a clean and unpolluted environment.

2) It is mainly applied by base stations and other small communication stations in places where summer is hot and winter is cold, or the temperature is moderate but there is big temperature gap between day and night.