Application of ALPHA Inverter in the Transformation Plan of Central Air-Conditioning

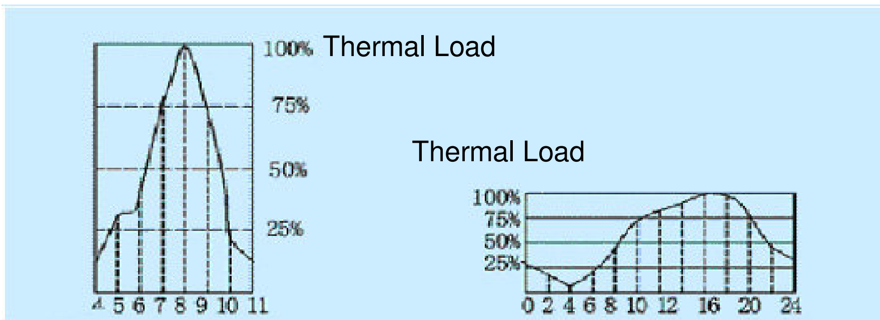
I. Principle of the Energy-Conservation Transformation of the Central Air-Conditioning System

1. System Analysis

In the central air-conditioning system, capacities of the chilled water pump and cooling water pump are chosen in accordance with the maximum design thermal load of the building, and certain margin should be left. It is operating under fixed maximum water flow on a long term basis, and due to change of season, day/night and the user load, the actual thermal load of the air-conditioning is lower than the design load for most of the time.

FIG.1 has shown the actual measured change of thermal load of one building. From FIG.1 we can see that compared with the maximum design load (load rate of 100%) which decides the flow and pressure of the water pump, situations under which the load rate is lower than 50% account for more than 50% of total operation. In general, the design temperature difference of chilled water is 5～7℃ and the design temperature difference of cooling water is 4～5℃; when the system has fixed flow, under most operation of the year, the temperature difference is only 1.0～3.0℃, i.e., it is operating with low temperature difference and big flow, which tends to increase energy loss in the pipeline system and waste delivery capacity of pump operation.

In accordance with the statistical analysis, generally speaking, power consumption of the water pump of air-conditioning accounts for 20～30% of that of the overall air-conditioning system, so it bears important significance to save the delivery capacity of the water system under low load. Therefore, the variable-flow water system of air-conditioning which can change in accordance with the thermal load has shown its huge superiority, and it has been more and more widely used. Adoption of inverter to regulate the rotation speed of the pump can conveniently regulate the water flow, the energy conservation rate of which is generally more than 40%.



Annual Change Diagram

Daily Change Diagram

FIG.1 Change Rate Curve of Thermal Load

2. Speed-regulation and energy-conservation principle of fan and pump load

Fan is a mechanical device to transmit gas and pump is a mechanical device to transmit fluid. Both fan and pump can transfer the shaft power of the motor to mechanical energy, they both have a small start torque and a light load, and they both have huge potential of energy conservation; these two devices also have fundamentally similar structures and operating principles. In the following, the operating principle and process of the pump will be analyzed:

1. Characteristics and parameter of the pump

The power only used for pumping the water is called active power.

Active power =(1000QH)/(75×60/0.736)=QH/6.11(kW)

Where, Q refers to the flow (m3/min); H refers to the total lift (m).

Assume the weight of 1m3 water is 1000kg within the lift, so

Shaft power of the pump =(Active power)/ Efficiency of the pimp (kW)

Output power of the motor=(1.05～1.2)×Shaft power (kW)

In accordance with different lifts and models of the pump, the pump also has different efficiencies. In general, efficiency curve of the general standard pump is like that shown in FIG. 2. Because there might be error in design and manufacturing of the pump, so the output power of the motor should have 5～20% surplus capacity compared with the shaft power, and then the power of the motor should be calculated in accordance with the flow and lift. FIG. 3 has shown the flow-lift characteristic curve.

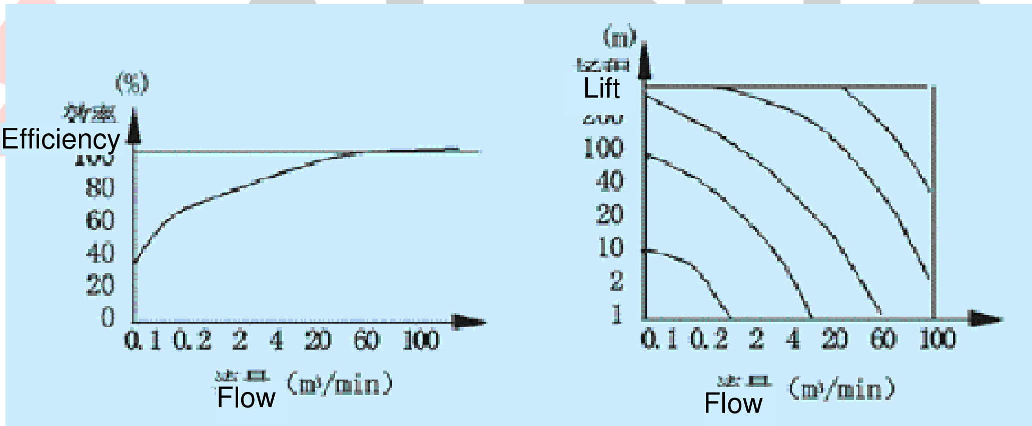


FIG. 2 Efficiency of General Standard Pump FIG. 3 Flow-Lift Characteristic Curve

2. Water resistance characteristic of the pipe network

When the water resistance R of the pipe network stays the same, the relation between the water volume and the rinsing resistance is not certain, i.e., the water volume Q and the rinsing resistance h change in accordance with the law of resistance, and its expression is:

$$H=RQ^2 \quad (Pa)$$

Where, H—rinsing resistance, R—water resistance coefficient.

H= f(Q) relation curve is the water resistance characteristic curve, which is in form of parabola, as shown in FIG. 4. From FIG. 4 we cans see that the bigger the water resistance coefficient R is, the steeper the curve, i.e., the bigger the rinsing resistance.

3. Principle of speed-regulation, control and energy conservation of the fan and pump
From fluid mechanics we can know that the water volume Q is in proportion to the rotation speed, the pressure H is in proportion to the square of rotation speed, and the power P is in proportion to the cube of rotation speed.

$$Q/Q_e = n/n_e$$
$$H/H_e = (n/n_e)^2$$
$$P/P_e = (n/n_e)^3$$

Where: Qe—Rated air (flow) volume of fan and pump;
He—Rated pressure of fan and pump;
Pe—Rated power of fan and pump;
ne—Rated rotation speed of fan and pump.

From the above formula we know that, if the efficiency of the pump is certain, when it is required turn down the water volume, the rotation speed will decrease proportionally, and at this moment, the shaft power of the water pump will decrease in accordance with the cube of the speed decrease.

In addition, in accordance with the characteristic curve of the water pump and the relation curve of the water resistance characteristic, we can obviously see the energy conservation effect of the fan and pump. FIG. 5 has shown the speed regulation and energy conservation schematic diagram of the fan and pump, in which, H refers to the H-f(Q) curve under constant speed, its water resistance curve and air resistance curve R1 intersect at point A, and the corresponding air volume is Q1. At this moment, the shaft power of the fan and pump is in proportion to the area of the rectangle Q1AH1Q. When it is required to reduce the air volume from Q1 to Q2 by using the baffle or valve, then the new air water resistance and resistance characteristic curves intersect at point B; at this moment, the shaft power of the fan is in proportion to the area of the rectangle Q2BH2Q.

If speed regulation is adopted to reduce the rotation speed of the fan and pump to n2 to make the corresponding fan characteristic curve H and air resistance characteristic curve R2 intersect at point C, then, at this moment, the shaft power of the fan which is in proportion to the area of the rectangle Q2CH3Q is significantly reduced, which means there the shaft power has been significantly reduced, and the energy conservation effect is obvious.

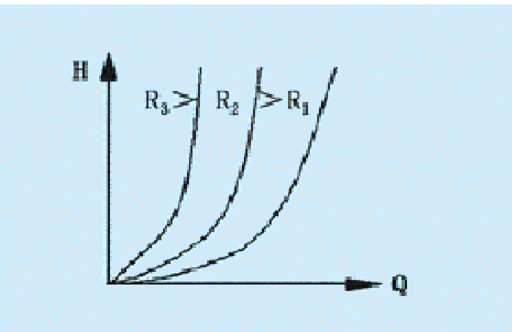


FIG.4 Water Resistance Diagram

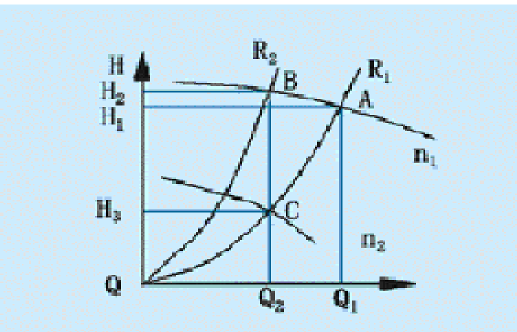


FIG.5 Pump Speed-Regulation and Energy-Conservation Schematic Diagram

II. System Control Mode

1. Chilled water system

For the chilled water system, its outlet water temperature depends on the set value of the evaporator, which is relatively fixed after setting. The return water temperature depends on the heat received by the evaporator. The maximum temperature difference between the chilled outlet water and return water in the central air-conditioning system is 5℃ (e.g., the temperature of the outlet water is 7℃ and the return water temperature is 12℃). The return water pipeline of currently adopted evaporator has been equipped with a closed-loop control system consisting of transmitter which can measure its temperature and the inverter, and the built-in PID regulator of the inverter controls the frequency conversion operation. One inverter controls two water pumps, of which, one water pump is directly driven by the inverter and the other is under the power frequency operation controlled by the inverter. When one water pump is not chilled adequately, the inverter operates to 50HZ and delay outputs the start signal of another water pump; when these two water pumps are chilled excessively, it operates with frequency conversion to the lower limit frequency, and delay outputs the stop signal of another water pump. Through control by the temperature difference of the chilled water (such as △T=5℃), the start/stop and rotation speed of the chilled water pump can change in accordance with the thermal load. See FIG.6 for the specific control mode.

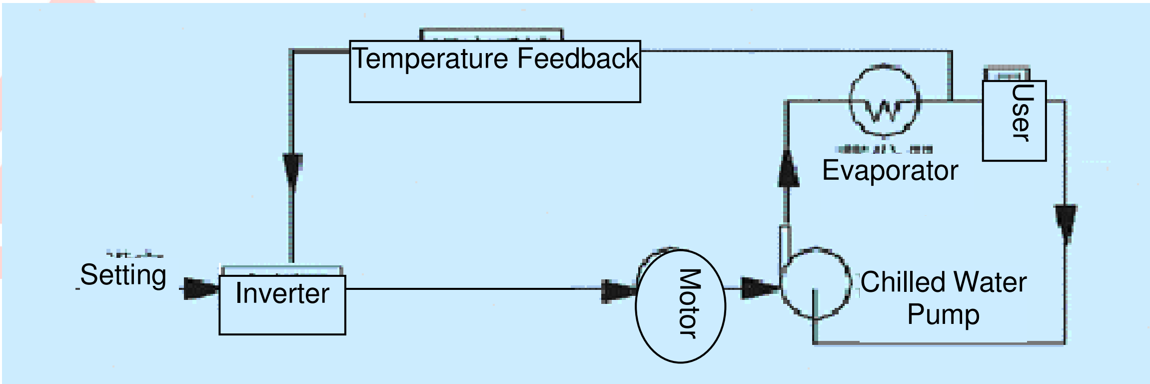


FIG.6 Control Mode of the Chilled Water Pump

2. Cooling water system

For the cooling water system, because the temperature of the low-temperature cooling water is under the impact of the operating situation of the cooling tower and the cooling fan as well as the environment temperature, it is not constant. Therefore, the temperature of the low-temperature cooling water (outlet water from the condenser) cannot totally reflect the cooling effect of the cooling water system, and only through control of the temperature difference can the cooling effect of the system and energy conservation be ensured.

The inlet/outlet pipeline of currently adopted condenser has been equipped with a sensor to measure its temperature. Signal from the sensor is sent to the closed-loop control system consisting of temperature difference transmitter and inverter, and the built-in PID regulator of the inverter controls the operation of inverter. One inverter controls two water pumps, of which, one water pump is directly driven by the inverter and the other is under the power frequency operation controlled by the inverter. When one water pump is not chilled adequately, the inverter operates to 50HZ and delay outputs the start signal of another water pump; when these two water pumps are chilled excessively, it operates with frequency conversion to the lower limit frequency, and delay outputs the stop signal of another water pump. Temperature difference between inlet/outlet water should be controlled at 4-5℃. One inverter is used to drive one cooling water pump to make the rotation speed of the cooling water pump change in accordance with the thermal load. See FIG.7 for the specific control mode.

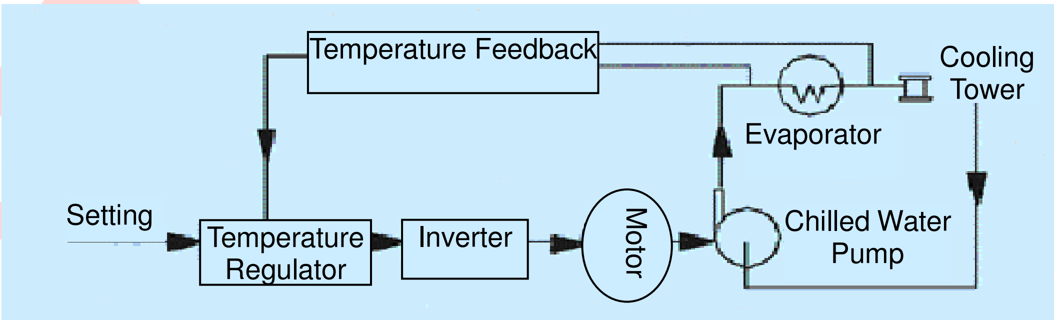


FIG.7 Control Mode of the Cooling Water Pump

III. Operating Mode Analysis of the Original System

The original circulating water system has two chiller water and cooling water systems. Current configuration is: 3 chilled pumps equipped with two motors of 75KW and one motor of 45KW and 3 cooling pumps equipped with two motors of 75KW and one motor of 45KW. At present, they are connected through valve, and the two systems share one pipeline. Start/stop of the water pump is entirely conducted manually, which has caused serious waste of energy.

IV. Transformation Plan I

1. The chiller water and cooling water systems both adopt the mode in which one inverter is used to control three water pumps.

Main system composition:

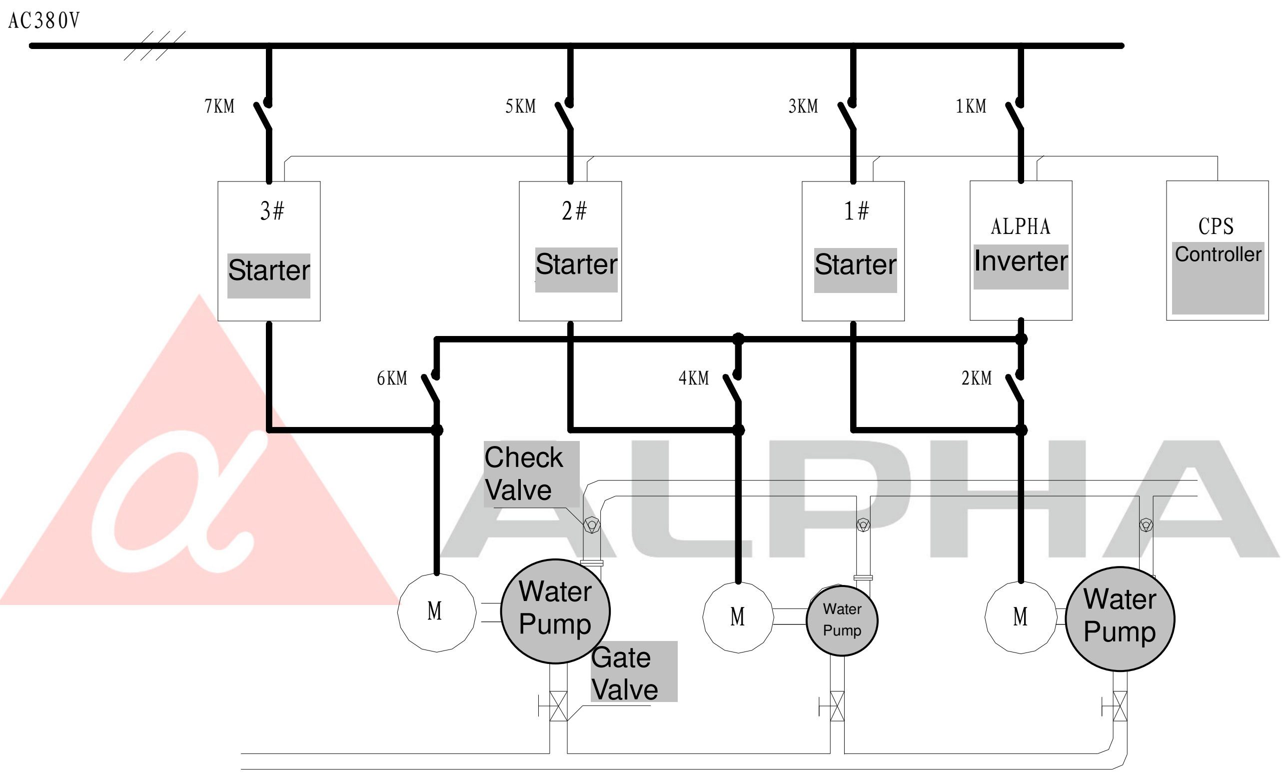
Two ALPHA6000-3075P inverters

Two CPS one-control-three controllers

Two 75KW control cabinets (each has seven conversion contractors)

Four thermal resistors and two temperature difference transmitters

2. System diagram (take one-drive-three for example, the big and small chiller water and cooling water belong to one system)



3. Main system functions

a. The pump unit will be automatically and circularly switched. When the system has been just put into operation, the temperature sensor T detects temperature difference on the inlet and outlet of the pipeline, transfers it into electrical signal and sends it to the microcomputer CPS for processing; if the temperature difference on the inlet and outlet of the pipeline is higher than the set value, it means the external load is high, then CPS will control the motor to conduct high-speed operation through the inverter until the water pump reaches the maximum rotation speed; at this moment, if the temperature difference on the inlet and outlet of the pipeline is still higher than the set value, then the system will automatically put another pump into power-frequency operation through delay, and the inverter will regulate the temperature difference of the pipeline to be constant. If the external load decreases and T detects temperature difference on the inlet and outlet of the pipeline to be lower than the set value, then CPS will automatically reduce the rotation speed of water pump through the inverter until the inverter reaches its lower limit frequency. If the temperature difference on the inlet and outlet of the pipeline is still lower than the set value, then the system will automatically cut off the pump water under the power-frequency operation through delay, and only water pump is under frequency-conversion regulation and operation. This process is repeated this way.

b. Automatic/manual switch. The system has two operating modes: during manual operation, personnel start the pump unit in accordance with load, and during automatic operation, CPS controls switching of the pump unit.

c. Free setting and switch of variable/fixed output pump. In order to ensure even usage ratio of various pump units to prevent rusting of any one pump unit, switch of variable/fixed output pump can be set through CPS.

V. Plan II

Both the big and small chiller water and cooling water systems have adopted the mode in which one inverter is used to control one water pump.

1. Main system composition:

   Four ALPHA6000-3075P inverters and two ALPHA6000-3045P inverters

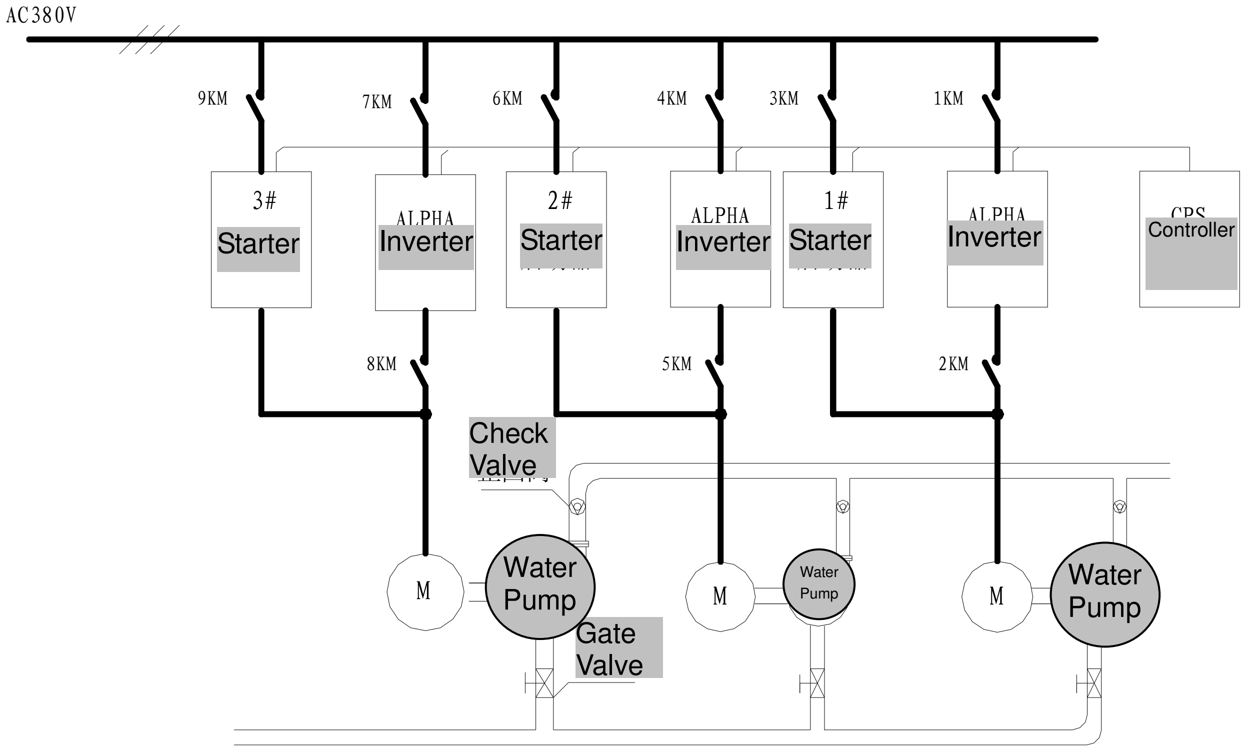
   Three CPS one-control-three controllers, one CPS one-control-two controller

   Four 75KW control cabinets (each has three conversion contractors)

   One 45KW control cabinet (containing six conversion contractors)

   Four thermal resistors and two temperature difference transmitters

2. System diagram (one-drive-one, the big and small chiller water and cooling water belong to one system)



3. Main system functions

a. The pump unit will be automatically and circularly switched.

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b. Automatic/manual switch. The system has two operating modes: during manual operation, personnel start the pump unit in accordance with load, and during automatic operation, CPS controls switching of the pump unit.

c. In addition to automatic/manual switch, various pump units can also compensate each other with high reliability.

VI. Comparison of the Two Plans

1. One-drive-three plan

   Advantage: small initial investment.

   Shortage: its energy conservation effect is not as good as the one-drive-one plan, there is huge impact during switching of pump unit, there is high failure rate of the switching contract, and reliability is bad.

2. One-drive-one plan

   Advantage: its energy conservation effect is better than the one-drive-three plan, the pump unit operates automatically with no need of manual regulation, it has pump compensation, and the system has high reliability.

   Shortage: big initial investment.

VII. Benefits for the users

Frequency-conversion closed loop is adopted to control the motor, and the temperature can be set in accordance with requirement, so that the reserve capacity of equipment and the thermal load which changes in accordance with the season can be regulated through rotation speed. Maximum energy conservation can be realized under the condition to satisfy the requirement of usage. In accordance with the transformations of the fans and water pumps of certain central air-conditioning systems, statistics and analysis of the comprehensive energy conservation rate of the whole year have been conducted, and the average energy conservation rate reaches 20～50%. In addition, the inverter also has the following characteristics in use:

1. It has complete protection functions for the motor, which includes protection against over-voltage, under-voltage, over-current and grounding protection.
2. Due to soft start of the inverter, water hammer impact on the circulating water pump during the start has been eliminated, and the equipment service life has been increased.
3. The inverter has a small start current, which has a small impact on the power system and in the benefit for its stable operation.
4. Because isolation by DC capacitor of the inverter makes the power factor of input close to 1 and the excitation reactive current of the motor is provided by the capacitor, in this way, about 30% capacity of the power system can be saved.
5. Since the energy conservation transformation by using the inverter, regulation of indoor temperature is smoother, and the comfort level is also increased.