Claims

1. An energy-saving optimized control system for a chiller plant room, which comprises an industrial control computer (1), a programmable controller (2), an RS485 communication interface module (3), a flow sensor (4), a temperature sensor (5), an outdoor temperature and humidity sensor (6), a three-phase active power transmitter (7), a differential pressure sensor (8), a water pump variable speed driver (9), a cooling tower fan variable speed driver (10), a motorized valve and on/off actuator (11) and chillers (12);
wherein,
the flow sensor (4), the temperature sensor (5), the outdoor temperature and humidity sensor (6), the three-phase active power transmitter (7), the water pump variable speed driver (9) and the cooling tower fan variable speed driver (10) respectively connect with the programmable controller (2),
the programmable controller (2) communicates with the industrial control computer (1) via the industrial Ethernet,
the RS485 communication interface module (3) connects with the chillers and communicates with the industrial control computer (1) via the ModBus protocol;
the temperature sensor (5) is used to respectively monitor the chilled water supply/return water temperatures and condenser water supply/return temperatures,
the outdoor temperature and humidity sensor (6) is used to monitor the dry bulb temperature and the relative humidity of the outdoor air, the flow sensor (4) is used to monitor the water flow rate during the operation of the water pump,
the three-phase active power transmitter (7) is used to monitor the operation energy consumption of the chillers, the water pump and the cooling tower,
the differential pressure sensor (8) is used to monitor the pressure difference at the air terminals,
the programmable controller (2) and the RS485 communication interface module (3) are used to acquire the data obtained by the sensors in real time,
and the industrial computer (1) is used to save the data and send out the operational control instructions.

2. The energy-saving optimized control system for a chiller plant room according to claim 1, wherein, the outdoor temperature and humidity sensor (6) is provided near an air intake opening of the outdoor cooling tower; the chilled water supply/return main pipes are respectively provided with the temperature sensors (5); the condenser water supply/return main pipes are respectively provided with the temperature sensor (5); the chilled water supply or return main pipes are mounted with the flow sensor (4); the condenser water supply or return main pipes are mounted with the flow sensor (4); the differential pressure sensor (8) is mounted between the chilled water supply main pipe and the chilled water return main pipe; the evaporator inlet and the condenser inlet of each chillers, and the water supply pipe and the water return pipe of each cooling tower are respectively mounted with the motorized valve and on/off actuators (11); and each chillers, each chilled water pump, each condenser water pump and each cooling tower are respectively mounted with the three-phase active power transmitter (7) .

3. The energy-saving optimized control system for a chiller plant room according to claim 2, wherein, the data acquired by the programmable controller (2) comprises the data obtained by the flow sensor (4), the temperature sensor (5), the outdoor temperature and humidity sensor (6), the three-phase active power transmitter (7) and the differential pressure sensor (8), and then the programmable controller (2) sends the above data to the industrial control computer (1), and the industrial control computer (1) saves the above data one by one with a predetermined time interval.

4. The energy-saving optimized control system for a chiller plant room according to claim 2, wherein, the RS485 communication interface module (3) performs the data acquisition of the parameters from the chillers including at least the chilled water entering/leaving temperatures, the condenser water entering/leaving temperatures, the condensing temperature, the condensing pressure, the evaporating temperature and the evaporating pressure, communicates with the industrial control computer (1) using a ModBus protocol and transfers the data information of the chillers, and saves them in the order of time.

5. The energy-saving optimized control system for a chiller plant room according to any one of claims 1 to 4, wherein, the industrial control computer (1) processes the data acquired by the programmable controller (2) and the RS485 communication interface module (3), and then sets the lowest energy consumption of the whole chiller plant room as an objective function, to determines the optimized energy-saving operation condition of each apparatus in the chiller plant room at the next moment, and transfers the results to the programmable controller (2) and the RS485 communication interface module (3).

6. The energy-saving optimized control system for a chiller plant room according to claim 5, wherein, the programmable controller (2) and the RS485 communication interface module (3) transfer the optimized operation condition to the adjusters of the corresponding apparatus, so as to make the apparatus operate under the optimized operation condition.

7. An energy-saving optimized controlling method for the chiller plant room, which comprises the following steps:

first step, establishing the mathematical models: according to a series of operational parameters from actual measurement of each apparatus in the chiller plant room, combining the default factory operational parameters of each apparatus, establish the mathematical model for the operational parameters and the energy consumption of each apparatus, and establish a calibration program at the same time;

second step, acquiring the real time data: at least obtain the parameters of the chilled water entering/leaving temperatures, the condenser water entering/leaving temperatures, the condensing temperature, the condensing pressure, the evaporating temperature, the evaporating pressure of the chillers, and obtain as well as the outdoor dry bulb temperature, the outdoor relative humidity, the chilled water supply temperature, the chilled water return temperature, the condenser water supply temperature, the condenser water retrun temperature, the chilled water flow rate, the condenser water flow rate, the power of the chillers, the power of the chilled water pump, the power of the condenser water pump and the power of the cooling tower, and save the data one by one with a predetermined time interval;

third step, calibrating the mathematical models: according to the real time operation data measured in the second step, call the calibration program to perform the real time calibration online to the mathematical models established in the first step;

fourth step, performing an optimization calculation: perform an optimization calculation with the objective of minimizing the sum of the energy consumption model of each apparatus, obtain the best operation condition for each apparatus in the chiller plant room, and perform a surge forecast for the chillers at the same time; when the chiller is about to face a potential surge, protection against surge is provided for the chillers in advance by adjusting the operation condition point of the chillers and the operation condition point restores to the former status automatically after the potential surge is eliminated;

fifth step, performing a feedback: transfer the best operation conditions obtained in the fourth step to each apparatus so that each apparatus will operate under the best operation condition, so that the whole chiller plant room will operate with the minimum energy consumption;

sixth step, repeating the third, the fourth and the fifth step with a predetermined time interval.

8. The energy-saving optimized control method for a chiller plant room according to claim 7, wherein, the mathematical models in the first step include the energy consumption model for chillers, the energy consumption model for chilled water pump, the energy consumption model for condenser water pump and the energy consumption model for cooling tower, said mathematical models are as follows:

$$P_{chiller} = \sum_{i=1}^{n_{Chiller}} \frac{Q_{nom,i}}{COP_{nom,i}} \cdot PLR_{adj,i} \cdot TEMP_{adj,i}$$

$$PLR_{adj} = a_0 + a_1\left(\frac{Q_{chiller}}{Q_{nom}}\right) + a_2\left(\frac{Q_{chiller}}{Q_{nom}}\right)^2$$

$$TEMP_{adj} = b_0 + b_1 T_{CHWS} + b_2 T_{CHWS}^2 + b_3 T_{CWS} + b_4 T_{CWS}^2 + b_5 T_{CHWS} \cdot T_{CWS}$$

$$P_{pump} = \frac{kQ_w^{\ 3} + H_{st.w}Q_w}{\eta_p \eta_c \eta_m} + P_{VFD}$$

$$P_{CHWpump} = \sum_{j=0}^{n_{CHWpump}} \sum_{J=0}^{3} c_{J,j} Q_{w_CHWpump}^{J}$$

$$P_{CWpump} = \sum_{k=0}^{n_{CWpump}} \sum_{K=0}^{3} d_{K,k} Q_{w_CWpump}^{K}$$

$$P_{CTfan} = \sum_{l=0}^{n_{CTfan}} \sum_{L=0}^{3} e_{L,l} Q_{air_CTfan}^{L}$$

$$Q_{rej} = \frac{x_1 m_w^{x_3}}{1 + x_2\left(\frac{m_w}{m_a}\right)^{x_3}} (T_{CWS} - T_{wb,i})$$

in the above fourth step of which, the algorithm for the optimization calculating is:

$$P_{chiller_plant} = Min(P_{chiller} + P_{CHWpump} + P_{CWpump} + P_{CTfan})$$

in which:

$P_{chiller}$: the energy consumption of chillers, kW;

$n_{Chiller}$: the number of chillers in operation;

Q_{nom}: the nominal capacity of chillers, kW;

COP_{nom}: the nominal COP of chillers;

PLR_{adj}: the part load regulating factor of chillers;

$TEMP_{adj}$: the temperature regulating factor of chillers;

a_0、a_1、a_2: the part load regulating factor coefficient of chillers;

$Q_{chiller}$: the actual cold quantity of chillers, kW;

b_0、b_1、b_2、b_3、b_4、b_5: the temperature regulating factor coefficient of chillers;

T_{CHWS}: chilled water entering temperature, ℃;

P_{pump}: the energy consumption of water pump, kW;

$H_{st.w}$: static pressure (only for open-type systems), mH_2O;

k: parameter relating to a pipe characteristic curve;

Q_w: water flow rate, kg/s;

η_p: water pump efficiency;

η_c: transmission efficiency;

η_m: electrical efficiency;

P_{VFD}: the energy consumption of variable speed driver, kW;

$P_{CHWpump}$: the energy consumption of chilled water pump, kW;

$n_{CHWpump}$: the number of chilled water pump in operation;

$c_{J,j}$: coefficient of chilled water pump;

$Q_{w_CHWpump}$: the flow rate of chilled water pump, kg/s;

P_{CWpump}: the energy consumption of condenser water pump, kW;

$d_{K,k}$: coefficient of condenser water pump;

Q_{w_CWpump}: flow rate of condenser water pump, kg/s;

n_{CWpump}: the number of condenser water pump in operation;

P_{CTfan}: the energy consumption of cooling tower, kW;

n_{CTfan}: the number of cooling tower in operation;

$e_{L,l}$: coefficient of cooling tower;

Q_{air_CTfan}: air rate of cooling tower, kg/s;

Q_{rej}: heat dissipating rate of cooling tower, kW;

m_w: condenser water flow rate, kg/s;

m_a: air flow rate, kg/s;

T_{CWS}: condenser water entering temperature, ℃;

$T_{wb,i}$: air wet bulb temperature, ℃.

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9. The energy-saving optimized control method for a chiller plant room according to claim 7 or 8, wherein, the minimum time interval for acquiring the real time data in the second step is set to 2 minutes.

10. The energy-saving optimized control method for a chiller plant room according to claim 7 or 8, wherein, in the sixth step, the minimal value of the time interval for repeating is 10 minutes.

Claims

1. An energy-saving optimized control system for a chiller plant room, which comprises an industrial control computer (1), a programmable controller (2), an RS485 communication interface module (3), a flow sensor (4), a temperature sensor (5), an outdoor temperature and humidity sensor (6), a three-phase active power transmitter (7), a differential pressure sensor (8), a water pump variable speed driver (9), a cooling tower fan variable speed driver (10), a motorized valve and on/off actuator (11) and chillers (12);

wherein,

the flow sensor (4), the temperature sensor (5), the outdoor temperature and humidity sensor (6), the three-phase active power transmitter (7), the water pump variable speed driver (9) and the cooling tower fan variable speed driver (10) respectively connect with the programmable controller (2),

the programmable controller (2) communicates with the industrial control computer (1) via the industrial Ethernet,

the RS485 communication interface module (3) connects with the chillers and communicates with the industrial control computer (1) via the ModBus protocol;

the temperature sensor (5) is used to respectively monitor the chilled water supply/return water temperatures and condenser water supply/return temperatures,

the outdoor temperature and humidity sensor (6) is used to monitor the dry bulb temperature and the relative humidity of the outdoor air, the flow sensor (4) is used to monitor the water flow rate during the operation of the water pump,

the three-phase active power transmitter (7) is used to monitor the operation energy consumption of the chillers, the water pump and the cooling tower,

the differential pressure sensor (8) is used to monitor the pressure difference at the air terminals,

the programmable controller (2) and the RS485 communication interface module (3) are used to acquire the data obtained by the sensors in real time,

and the industrial computer (1) is used to save the data, to establish the mathematical model for operational parameters and the energy consumption of each apparatus according to a series of operational parameters from actual measurement of each apparatus in the chiller plant room, combining the default factory operational parameters of each apparatus, and establish a calibration program at the same time; and the industrial computer (1) is used to call the calibration program according to the data saved, to perform the real time online calibration to the mathematical models; and the industrial computer (1) is used to perform an optimization calculation according to the calibrated mathematical models to obtain the best operation condition of each apparatus in the chiller plant room; and the industrial computer (1) is used to send out the operational control instructions.

2. The energy-saving optimized control system for a chiller plant room according to claim 1, wherein, the outdoor temperature and humidity sensor (6) is provided near an air intake opening of the outdoor cooling tower; the chilled water supply/return main pipes are respectively provided with the temperature sensors (5); the condenser water supply/return main pipes are respectively provided with the temperature sensor (5); the chilled water supply or return main pipes are mounted with the flow sensor (4); the condenser water supply or

return main pipes are mounted with the flow sensor (4); the differential pressure sensor (8) is mounted between the chilled water supply main pipe and the chilled water return main pipe; the evaporator inlet and the condenser inlet of each chillers, and the water supply pipe and the water return pipe of each cooling tower are respectively mounted with the motorized valve and on/off actuators (11); and each chillers, each chilled water pump, each condenser water pump and each cooling tower are respectively mounted with the three-phase active power transmitter (7) .

3. The energy-saving optimized control system for a chiller plant room according to claim 2, wherein, the data acquired by the programmable controller (2) comprises the data obtained by the flow sensor (4), the temperature sensor (5), the outdoor temperature and humidity sensor (6), the three-phase active power transmitter (7) and the differential pressure sensor (8), and then the programmable controller (2) sends the above data to the industrial control computer (1), and the industrial control computer (1) saves the above data one by one with a predetermined time interval.

4. The energy-saving optimized control system for a chiller plant room according to claim 2, wherein, the RS485 communication interface module (3) performs the data acquisition of the parameters from the chillers including at least the chilled water entering/leaving temperatures, the condenser water entering/leaving temperatures, the condensing temperature, the condensing pressure, the evaporating temperature and the evaporating pressure, communicates with the industrial control computer (1) using a ModBus protocol and transfers the data information of the chillers, and saves them in the order of time.

5. The energy-saving optimized control system for a chiller plant room according to any one of claims 1 to 4, wherein, the industrial control computer (1) processes the data acquired by the programmable controller (2) and the RS485 communication interface module (3), and then sets the lowest energy consumption of the whole chiller plant room as an objective function, to determines the optimized energy-saving operation condition of each apparatus in the chiller plant room at the next moment, and transfers the results to the programmable controller (2) and the RS485 communication interface module (3).

6. The energy-saving optimized control system for a chiller plant room according to claim 5, wherein, the programmable controller (2) and the RS485 communication interface module (3) transfer the optimized operation condition to the adjusters of the corresponding apparatus, so as to make the apparatus operate under the optimized operation condition.

7. An energy-saving optimized controlling method for the chiller plant room, which comprises the following steps:
first step, establishing the mathematical models: according to a series of operational parameters from actual measurement of each apparatus in the chiller plant room, combining the default factory operational parameters of each apparatus, establish the mathematical model for the operational parameters and the energy consumption of each apparatus, and establish a calibration program at the same time;
second step, acquiring the real time data: at least obtain the parameters of the chilled water

entering/leaving temperatures, the condenser water entering/leaving temperatures, the condensing temperature, the condensing pressure, the evaporating temperature, the evaporating pressure of the chillers, and obtain as well as the outdoor dry bulb temperature, the outdoor relative humidity, the chilled water supply temperature, the chilled water return temperature, the condenser water supply temperature, the condenser water retrun temperature, the chilled water flow rate, the condenser water flow rate, the power of the chillers, the power of the chilled water pump, the power of the condenser water pump and the power of the cooling tower, and save the data one by one with a predetermined time interval;

third step, calibrating the mathematical models: according to the real time operation data measured in the second step, call the calibration program to perform the real time calibration online to the mathematical models established in the first step;

fourth step, performing an optimization calculation: perform an optimization calculation with the objective of minimizing the sum of the energy consumption model of each apparatus, obtain the best operation condition for each apparatus in the chiller plant room, and perform a surge forecast for the chillers at the same time; when the chiller is about to face a potential surge, protection against surge is provided for the chillers in advance by adjusting the operation condition point of the chillers and the operation condition point restores to the former status automatically after the potential surge is eliminated;

fifth step, performing a feedback: transfer the best operation conditions obtained in the fourth step to each apparatus so that each apparatus will operate under the best operation condition, so that the whole chiller plant room will operate with the minimum energy consumption;

sixth step, repeating the third, the fourth and the fifth step with a predetermined time interval.

8. The energy-saving optimized control method for a chiller plant room according to claim 7, wherein, the mathematical models in the first step include the energy consumption model for chillers, the energy consumption model for chilled water pump, the energy consumption model for condenser water pump and the energy consumption model for cooling tower, said mathematical models are as follows:

$$P_{chiller} = \sum_{i=1}^{n_{Chiller}} \frac{Q_{nom,i}}{COP_{nom,i}} \cdot PLR_{adj,i} \cdot TEMP_{adj,i}$$

$$PLR_{adj} = a_0 + a_1\left(\frac{Q_{chiller}}{Q_{nom}}\right) + a_2\left(\frac{Q_{chiller}}{Q_{nom}}\right)^2$$

$$TEMP_{adj} = b_0 + b_1 T_{CHWS} + b_2 T_{CHWS}^2 + b_3 T_{CWS} + b_4 T_{CWS}^2 + b_5 T_{CHWS} \cdot T_{CWS}$$

$$P_{pump} = \frac{kQ_w^{\ 3} + H_{st.w}Q_w}{\eta_p \eta_c \eta_m} + P_{VFD}$$

$$P_{CHWpump} = \sum_{j=0}^{n_{CHWpump}} \sum_{J=0}^{3} c_{J,j} Q_{w_CHWpump}^{J}$$

$$P_{CWpump} = \sum_{k=0}^{n_{CWpump}} \sum_{K=0}^{3} d_{K,k} Q_{w_CWpump}^{K}$$

$$P_{CTfan} = \sum_{l=0}^{n_{CTfan}} \sum_{L=0}^{3} e_{L,l} Q_{air_CTfan}^{L}$$

$$Q_{rej} = \frac{x_1 m_w^{x_3}}{1 + x_2 \left(\frac{m_w}{m_a} \right)^{x_3}} (T_{CWS} - T_{wb,i})$$

in the above fourth step of which, the algorithm for the optimization calculating is:

$$P_{chiller_plant} = Min(P_{chiller} + P_{CHWpump} + P_{CWpump} + P_{CTfan})$$

in which:

$P_{chiller}$: the energy consumption of chillers, kW;

$n_{Chiller}$: the number of chillers in operation;

Q_{nom}: the nominal capacity of chillers, kW;

COP_{nom}: the nominal COP of chillers;

PLR_{adj}: the part load regulating factor of chillers;

$TEMP_{adj}$: the temperature regulating factor of chillers;

a_0、a_1、a_2: the part load regulating factor coefficient of chillers;

$Q_{chiller}$: the actual cold quantity of chillers, kW;

b_0、b_1、b_2 、b_3、b_4、b_5: the temperature regulating factor coefficient of chillers;

T_{CHWS}: chilled water entering temperature, ℃;

P_{pump}: the energy consumption of water pump, kW;

$H_{st.w}$: static pressure (only for open-type systems), mH_2O;

k: parameter relating to a pipe characteristic curve;

Q_w: water flow rate, kg/s;

η_p: water pump efficiency;

η_c: transmission efficiency;

η_m: electrical efficiency;

P_{VFD}: the energy consumption of variable speed driver, kW;

$P_{CHWpump}$: the energy consumption of chilled water pump, kW;

$n_{CHWpump}$: the number of chilled water pump in operation;

$c_{J,j}$: coefficient of chilled water pump;

$Q_{w_CHWpump}$: the flow rate of chilled water pump, kg/s;

P_{CWpump}: the energy consumption of condenser water pump, kW;

$d_{K,k}$: coefficient of condenser water pump;

Q_{w_CWpump}: flow rate of condenser water pump, kg/s;

n_{CWpump}: the number of condenser water pump in operation;

P_{CTfan}: the energy consumption of cooling tower, kW;

n_{CTfan}: the number of cooling tower in operation;

$e_{L,l}$: coefficient of cooling tower;

Q_{air_CTfan}: air rate of cooling tower, kg/s;

Q_{rej}: heat dissipating rate of cooling tower, kW;

m_w: condenser water flow rate, kg/s;

m_a: air flow rate, kg/s;

T_{CWS}: condenser water entering temperature, ℃;

$T_{wb,i}$: air wet bulb temperature, ℃.

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9. The energy-saving optimized control method for a chiller plant room according to claim 7 or 8, wherein, the minimum time interval for acquiring the real time data in the second step is set to 2 minutes.

10. The energy-saving optimized control method for a chiller plant room according to claim 7 or 8, wherein, in the sixth step, the minimal value of the time interval for repeating is 10 minutes.