Implementation of a web-based global optimal management system in district cooling

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ABSTRACT
Traditionally the optimal management of district cooling usually takes into account the system's technical or economical performances only. This paper presents a web-based approach, which considers not only technical and economical but also environmental and humanistic factors in the lifecycle of district cooling, and employs diverse measures in difference phases of the district cooling system such as designing, construction, commission and operation. After being implemented in a project in South China, this approach has proven to be applicable and effective, and can achieve the dual goal of energy conservation and environmental protection successfully.

INDEX TERMS
District cooling; Global optimal management; Web-based; Systems engineering

INTRODUCATION

Building energy plays an essential role in global energy consumption. In China, as a developing country, building energy accounts for about 20% of total energy consumption, 85% of which goes to HVAC (Heating, Ventilation and Air Conditioning) systems in buildings. About 75% of electric power in China is generated from burning coal, which emits considerable pollutants during its burning process. The dual goal of energy conservation and environmental protection will be achieved by implementing an energy optimal management system in buildings.

DCS (District Cooling System) provides chilled water generated by one or more chillers to satisfy residents' demand for air conditioning through a large-scale distribution system. Having the advantages of high energy-efficiency and low environmental impact, the DCS is quite popular in Europe, America and Japan and displays a promising future (Yoshihiko *et al.*, 1998). Due to the complicacy of the DCS, the conception of systems engineering should be introduced into DCS optimal management.

After considerable research work, a web-based DCOMS (District Cooling Optimal Management System) has been implemented in a project presented in this paper, which considers not only technical and economical but also environmental and humanistic factors in the lifecycle of DCS, and employs diverse measures in difference phases of the DCS such as designing, construction, commission and operation.

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THE COMPOSITIONS OF DCOMS

There are four subsystems involved in DCOMS. The chiller plant decision-making subsystem, which employs AHP (Analytical Hierarchy Process), makes an optimal decision based on various factors. The district cooling optimal design subsystem adopts a combination of thermodynamic and economic analysis to optimize the design scheme. Some artificial intelligence methods are utilized in district cooling coordination control subsystem to achieve a global optimal management. The residents' charges for distract cooling are calculated by the district cooling energy cost allocation subsystem. Finally, all of above four subsystems are integrated into an entire system by Lonworks technology, and can be manipulated in distance through Internet. The schematic configuration of DCOMS is shown in Figure 1.

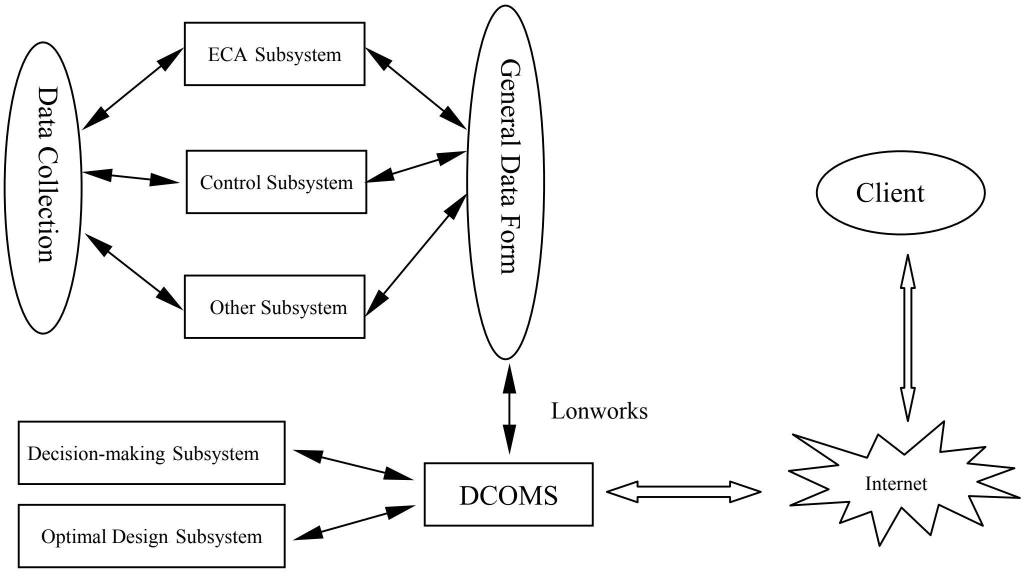

Figure 1 District cooling optimal management system.

Chiller Plant Decision-making Subsystem

Traditionally, the chiller plant decision-making subsystem usually takes into account only one factor of DCS, such as technique or economy, but not all the intricate factors, so it is impossible to draw out a reasonable decision. The AHP method, developed in 1970s by Prof. T.L. Saaty, is employed in the chiller plant decision-making subsystem presented in this paper. As a systematic analytical method, AHP incorporates objective data, experts' opinions and analytical personnel's judgements effectively (Saaty, 1988). As several factors about chiller plant decision cannot be determined directly or easily, such as the environmental impacts of DCS and the system reliability, the AHP method is perfectly suitable for the chiller plant decision-making subsystem (Lin, 2002).

District Cooling Optimal Design Subsystem

After the types of chiller plants are determined by the chiller plant decision-making subsystem according to the characteristics of the project, the district cooling optimal design subsystem, which employs computer simulation technology and a combination of thermodynamic analysis and LCC (Life Cycle Cost) analytical method (NIST, 1995), can be introduced into the design the design process to draw out the optimal configuration of DCS. Through simulating the DCS's energy consumption with a modified bin method (ASHRAE, 1985), a series of design variables of DCS are optimized, and then an optimal configuration of DCS is arrived at successfully (Chen, 2002).

District Cooling Coordination Control Subsystem

A typical DCS consists of several sections. Traditional management systems adopt control strategy individually, which ignores the interactions among sections and lacks an integrated optimal control objective, so they are not suitable for DCSs. With the help of technology development, the district cooling coordination control subsystem presented here considers the interactions of different sections and takes the entire DCS as its optimal control objective. Some artificial intelligence methods, such as neural networks and genetic algorithms, are adopted to achieve the global optimal management. Finally, the variable frequency technique, which features a perfectly energy conservation for pumps and fans, is employed to guarantee the DCS operating under a high-efficiency status (Chen, 2001).

District Cooling Energy Cost Allocation Subsystem

In China, due to various reasons, charging in the district cooling system still employs the traditional method, by which residents pay according to the floor area they occupied. It results in serious energy wastage (Yu, 2001). On the contrary, ECA (Energy Cost Allocation) calculates energy cost with residents' actual energy consumption, and can stimulate the initiative of the building residents' to save energy (Scott, 1991). After analysing the current ECA methods elaborately, a new ECA method based on justice and practicability has been advanced, which takes into account the discrepancy of building envelopes and heat transfer between adjacent apartments carefully. Based on this ECA method, a district cooling cost allocation subsystem is implemented, which can meter residents' district cooling energy consumption and allocate the charge of DCS and decrease energy wastage (Yu, 2001).

IMPLEMENTATION BASED ON NETWORK ENVIRONMENT

After a comprehensive analysis of the characteristics of DCS and communication technology, LonTalks communication protocol, which is based on Lonworks technology, is adopted in DCOMS as its communication protocol to integrate these subsystems, such as coordination control subsystem, ECA subsystem and some other control or management subsystems.

For having a flexible structure, Lonworks network can employ different connection patterns according to the project installation. Lonworks network has other prominent characters, such as high reliability, convenient maintenance, strong expandability. Since it adopted a uniform data structure, the data collected by one device can be shared all over the system conveniently, which will lead to huge saving of initial investment. As an open communication protocol, by which devices can interconnect directly and build up a non-host point-to-point distributed system easily, Lonworks technology is popular in more than 3000 famous enterprises world-wide and has become an industry standard of field-buses.

The TCP/IP communication protocol is embedded in every Neuron Chip, which constructs the frame of the Lonworks network, so DCOMS can also be manipulated through the Internet conveniently. With the help of DCOMS, the decision makers, operation personnel and managers can execute supervising and control the DCS in remote, which will save a great deal of money, time and material in general management.

AN APPLICATION CASE

On the request of the Housing Authority of Shenzhen city, a tropic city in South China, a DCS schematic design of a tremendous residential district, which will hold dwelling apartments for more than 30 000, was drawn out by employing DCOMS. Based on the construction plan of this district, there are three sub-DCSs (A, B and C) that will be implemented. The details of these sub-DCSs are shown in Table 1.

Table 1 The detailed description of DCS

	A sub-DCS	B sub-DCS	C sub-DCS	Total DCS
Dwelling apartments	13 337	8691	9212	31 240
Design load (kW)	56 015	36 502	38 690	131 207

The following are some key points of the DCS schematic design of this project:

Alternatively chiller plants in DCS commonly include compression units (centrifugal type and screw type) and absorption units (direct-fired type and vapour type). Considering the local energy policy and market of Shenzhen city, initial investment, operation costs, system reliability and environmental impacts, it is more economical and environmentally preferable to adopt direct-fired type absorption chillers which utilize natural gas in this project.

With a large coverage and huge transportation, there is significant energy consumption, initial investment and heat loss for DCS's chilled water distribution system. After an optimization, which takes the economic performance of the whole DCS throughout its lifecycle as its optimization objective, it is found that there is an optimum of chilled water temperature difference and the optimum is varied based on the coverage of the DCS. Generally, the optimum is about 8–9°C, and in this project, the optimum is 8.4°C.

After several key parameters of DCS, such as cooling water flow rate, chilled water flow rate, cooling water inlet temperature, chilled water inlet temperature, unit energy consumption, and so on, are measured in real-time, the optimal status of the whole DCS is calculated by the central computer employing an artificial intelligence algorithm and executed by all devices through the Lonworks network instantly. Then, the DSC is always conducted in the optimal status, in which significant energy conservation will be realized.

A chilled water system with distributed secondary pumps has been recommended in this project, which manipulates the variable-speed pump according the angle of terminals' control valves: Pump speed decreases when no control valve of the terminals is full-open and cooling capacity is sufficient to meet current load; Pump speed increases when all control valves of terminals are full-open while cooling capacity is inadequate to meet current load; Pump speed is constant when some control valves of the terminals are full-open and cooling capacity is sufficient to meet current load.

A three-level structure, which consists of a system management host, zone processors and field data collectors is introduced to the ECA system of this project, and the RS-485 data bus is adopted to maintain communication between host and processors and collectors. In this ECA system, the management host can administer 32 zone processors, and each zone processor is linked to 255 data collectors, which manipulates four users synchronously, so such an ECA such an ECA system can contain more than 30 000 users altogether.

In view of installation and the district construction scheme, there is an independent ECA system for each sub-DCS, but all three ECA systems can be linked to the district administration centre by Lonworks field-bus. The other subsystems in this residential district, such as coordination control subsystem, safety automation subsystem and fire automation subsystem, etc., all can be connected with the district administration centre through this Lonworks network too, and share the data with each other freely.

CONCLUSIONS

The implementation of global optimal management for DCS is an arduous task, which can only be settled by employing the conception of systems engineering. After being implemented in an actual project in South China, the DCOMS proposed in this paper has proven to be applicable and effective, and can achieve the objective of energy conservation and environment protection successfully. That is, the DCOMS provides a powerful tool for global sustainable development and has a promising future.

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