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Research on Integration of Heating Network Management and Control Based on Cloud Computing

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The purpose of this study is to better provide optimal control schemes and management services for heating enterprises. To this end, a cloud computing-based integrated heating network management and control system was introduced in this paper. Based on cloud computing service, a platform for integrated management and control was established. Besides, the combined control scheme of equipment management and control was proposed, and research on its technical issues was conducted. The results show that this scheme has significant adaptability. Thus, it can be used in the internal system of heating enterprises in the future.

1. Introduction

China is a big energy consumer. The management model of China's heating industry still has a huge gap with the international advanced management level. With the acceleration of the industrialization process and the improvement of the technical level, the urban framework has been continuously expanded, the scale of heating has also been expanding, and the information management of heating systems has entered the era of big data. The speed of informatization construction supported by big data and cloud computing services has been accelerating, which has promoted the development of modern enterprises towards intelligence. How to improve the information management level and decision-making level of heating system to adapt to heating demand has always been a difficult and hot topic in this field.

In order to improve the level of enterprise information construction, this paper will also explore how to build an integrated intelligent control platform to achieve data mining, data analysis and decision support. The system makes full use of the asynchronous computing and parallel processing capability of the cloud platform to control the key nodes of the heating network to run a heat station, so as to eliminate the hysteresis of the heating network operation, break the information island effect of each heating station, and promote the optimal scheduling of thermal resources. To enhance the level of information management and decision-making in the field of heating. This will provide technical support for future related work.

2. Literature review

In a heating network, energy storage is a viable way to balance demand and supply. In such networks, the heat carrier is used in the form of water. Heat is injected and extracted through the heat exchanger. The network can transport and store hot water in a tiered tank to transfer loads in a timely manner. For this topology, the model consists of differential equations describing temperature and volume dynamics. A controller was designed to converge both volume and temperature to a specified set point (Tesi, 2015). A significant heat loss rate was found on the distribution line of the simulated district heating apartment building. At the same time, the control of the water supply temperature and mass flow can minimize the heat loss on the distribution line, and the concept of the limit hot water supply temperature is adopted. By selecting this heating control algorithm, the heat loss of the community building distribution line can be reduced to 13.6% (Byun et al., 2015). The concept of a new virtual power system (VPS) and distribution power & energy internet operator (DEIO) is proposed. VPS are highly integrated and leverage Internet of Things (IOT) and cloud computing technologies to take into account local infrastructure constraints and constraints when virtual power plant aggregation and optimization. DEIO are mainly responsible for aggregating and coordinating multiple

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virtual power plants in the virtual power system. In addition to the power distribution network, they are also responsible for the coordination and integration of electricity, gas and heat networks within the region. (Zhang, et al., 2015). Heat transfer between the process and the recycle stream can lead to instability. Therefore, advanced control technology has the challenging task of ensuring process safety and providing tight control of the heat integrated device. Thermal integration is designed and operated for the complex dynamics of catalytic cracking units (Iancu et al., 2013). Bypassing is provided on the heat exchange network to enhance heat exchange network control and enable optimal operation of the equipment. Then, taking the cumulative total cost increment of the heat exchanger network (including the increase of utility cost and equipment investment cost) as the objective function, the optimal design margin of the heat exchanger network is solved (Luo et al., 2013). The deterministic MPC algorithm is used to optimize the optimal setpoint trajectory of the TES tank, which reduces the power consumption of the heat pump by 34.5%. The influence of the prediction uncertainty of horizontal solar irradiance on the performance of the predictive controller was also studied. When the prediction error is greater than 38%, the results have a considerable impact on thermal comfort conditions (Li et al., 2015). The optimization of the hydraulic conditions of the heating system was discussed. Studies have shown that when the main operational control method is adopted, including the control of the pump number connected to the pump station, the problem is reduced to a mixed discrete-continuous programming problem involving a nonlinear objective function and a nonlinear equation constant (Novitsky and Lutsenko, 2016) Gas/electric/thermal hybrid networks are highlighted. Hydrogen storage systems (fuel cells, electrolyzers, and storage tanks) are used as storage systems. Cogeneration units are used to generate heat and electricity. The goal is to minimize the load on the shed. Genetic algorithms are used to search for the optimal size of each component to minimize the total investment cost (Li et al., 2018). The modeling and control of the regenerative heat network was studied. During the study, the heat extracted was unknown, and the flow through the user heat exchanger was set to a measurable constant. Both the flow and the producer's thermal injection are used as control inputs. The controller uses output regulation technology. While meeting the requirements, the specified set points are reached (Scholten et al., 2017). The heating, cooling and power load forecasting of large regional energy systems were studied. The cold, heat and electrical loads of the regional energy system are predicted. Several different model types were compared, including linear and nonlinear, static and time series. Nonlinear ARX (autoregressive model with exogenous input) model is more suitable for prediction. Uts includes time variables that reflect occupancy and weather, and the fitted data is used to compare model accuracy for all model types (Powell et al., 2014). A new method for temperature fault detection and quality assurance of faults is proposed. Temperature difference fault analysis was performed on the hourly data sets of 140 substations. In the 140 substations, 14 substations have experienced or eliminated temperature differences (Gadd and Werner, 2014).

To sum up, the above research work is mainly based on the conventional way to achieve the study of heating network management and control. Low reflux temperature in distribution network is an important operational factor for obtaining efficient district heating system. In order to achieve low reflow temperatures, user substations and secondary heating systems must perform no temperature faults. In the future fourth generation district heating system, a lower distribution temperature will be required. There are not many researches related to cloud network-based integration of heat network management and control. Under the cloud computing concept, a hot network management and control integration solution was proposed for practical application and research in future heating enterprises.

3. Methods

3.1 System Architecture

The system architecture of cloud computing is shown in Figure 2.

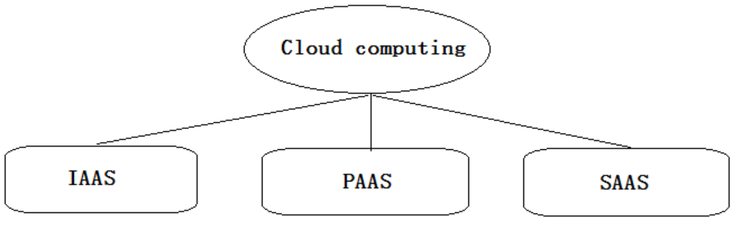

Figure 1: Cloud computing architecture diagram

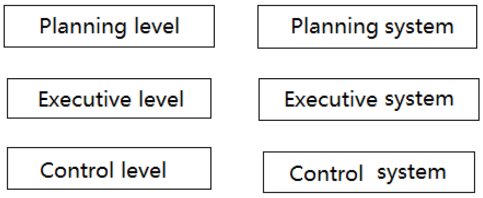

Figure 2: Enterprise integration layer model

With the introduction of the “Industry 4.0” concept, the network communication technology has been combined with big data services, to further promote the integration of informationization and industrialization, and accelerate the “smart” production and management of modern enterprises.

The three-tier integrated model currently used by manufacturing enterprises consists of enterprise planning management layer (ERP), manufacturing execution layer (MES), and process control layer (PCS). Enterprises need to build their own data servers to analyse, count, and make decisions about production and management data. Data service centres require professional maintenance and regular upgrades. Various internal automation control systems of the enterprise are controlled separately by controllers of different manufacturers. The control programs are stored in their respective field controllers, and special technicians are required to perform on-site programming and debugging. Therefore, the establishment and maintenance of the system requires higher costs.

3.2 Integrated platform

The cloud-based integrated heating network management and control platform consists of a cloud computing data centre, an intelligent control terminal, and various management analysis software, as shown in Figure 3. The system connects each heating station control terminal of the heating enterprise in real time, collects and stores data in the database of the cloud computing centre. Only by using mobile phones, tablets computers, computers and other devices to connect the network, users can access the cloud computing centre; make real-time monitoring through the control platform, and query, statistics and analysis of the running data, so as to obtain the control optimization strategy, release control commands, and adjust operating parameters. Enterprises do not need to build their own data centres, nor do they need to perform complex logic programming, which can greatly reduce operational management costs.

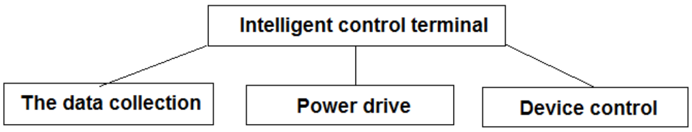

Figure 3: The integrated architecture of heat network management and control based on cloud computing

3.3 Data collection

The real-time data server collects and controls the data on the field device through the GPRS wireless communication link. The real-time data server is configured with redundancy to ensure that the data collection and storage work on site is secure and uninterrupted. Geographic Information System (GIS) technology is used to store, manage, maintain, and update graphical data and attribute data for various devices in the hot network to easily locate and retrieve relevant information. Meanwhile, this system is closely integrated with other systems of charging, customer service and production, which facilitates the planning and management of heat-supply pipe network, as well as the analysis of hot water supply and energy consumption, thus helping users to manage thermal facilities and organizations more conveniently, effectively and economically. The system can collect the temperature, pressure, flow, heat, valve opening and other parameters of each control station and the operating status of the equipment in real time, and visually display the process flow and heating quality of each control station, as shown in Figure 4.

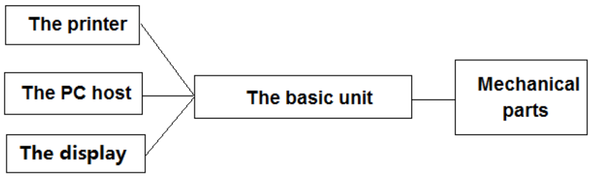

Figure 4: Real time monitor working diagram

3.4 Analytical calculation

The details are shown in Figure 5.

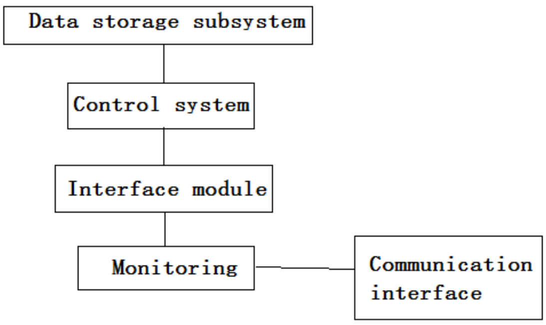

Figure 5: Condition monitoring system

Using the collected data information, through the hydraulic analysis balance software, the resistance characteristic coefficient and flow distribution of each pipeline in the heating network can be identified in real time, and the water pressure map can be drawn to fully understand the hydraulic and thermal conditions of the whole system. Due to the differences between construction and design, as well as changes in heating area, there will be hydraulic imbalances in the pipe network. The balance of the whole network is the coordinated control of all the heat stations in essence, which supplies heat according to the planned heat index, that is, the heat supply of the heat source does not exceed the standard by controlling all the heat stations, thereby achieving the purpose of controlling the heating cost. The planned heat index varies with the outdoor temperature. The analysis of heating energy management is to monitor, analyse and comprehensively calculate the energy consumption data of heat, water and electricity uploaded to the cloud computing data centre, including: total energy consumption daily report, monthly report, and comparison of the same period; historical energy consumption trend analysis of single thermal station and multiple thermal stations; comparison of energy consumption per unit of multiple thermal stations. Different energy consumption indicators for various heat sources such as heat, water and electricity for each thermal station should be established, and under the premise of ensuring the user's heating effect, the resources can be rationally utilized in a planned manner so as to minimize the unit energy consumption and achieve safety the purpose of applying energy efficiently and reasonably.
At the same time, according to different algorithms (external temperature load curve, historical experience value, etc.), the system can automatically calculate the ideal heating adjustment based on real-time working conditions, weather forecast, actual heating load and other information. Then, combined with the judgment of dispatchers, the actual dispatching operation plan in different periods can be finally formulated to guide the specific work of the dispatchers. Thus, it can be used as the judgment basis for the later heat supply dispatch analysis.

4. Results and analysis

4.1 Remote control results

The speed control mode of variable frequency circulating pump includes manual setting, speed climate compensation control, climate compensation control for return water pressure difference, and climate compensation control for return water temperature difference. The system determines the water supply temperature of the secondary side according to the change of the outdoor temperature, performs PID adjustment, controls the opening degree of the regulating valve, and changes the flow rate of the primary side. The working principle is shown in Figure6. The quality adjustment of the secondary side water supply temperature and the quantity adjustment of the primary side flow can also be realized. The system can set the parameters such as the water supply pressure, sleep frequency and wake-up deviation of the make-up water pump. Based on the deviation of the secondary water return pressure and the set value, the running frequency of the make-up water pump is automatically controlled to realize the secondary network water supply automatic replenishment.

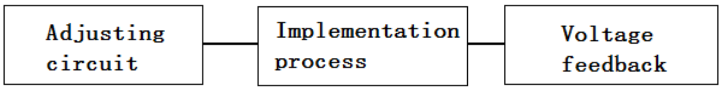

Figure 6: The PID

4.2 Customer service system

The customer service system realizes the automatic management of the user reception, and through the statistical data, uses the short message to realize the automatic dispatch of the business and the customer's payment. It also provides the defect record data and the repair order data, and prints the form. It has targeted solutions for the pipe network and users to the common fault points, to avoid the recurrence of the problem, and achieve closed-loop management of fault handling. Its recording function provides a basis for the user's disputes to be investigated.

4.3 Data resource management

The charging system platform realizes digitalization and networking of heating charges, and centralized management of charging information. It can improve business operation efficiency and quality, completes enterprise management system, strengthens enterprise management and supervision functions, effectively controls costs, and maximizes profits. The data centre is a large server cluster. Different service functions such as data collection, system monitoring, meteorological management, hydraulic calculation, energy analysis, charging, and customer service system are deployed in different servers. In order to meet the functional requirements of the system for storage, retrieval speed, and simultaneous storage and retrieval of real-time and historical data by multiple concurrent users, it is necessary to introduce automated control technology to coordinate and manage various data resources. Thus, it can improve computing efficiency and avoid cumbersome details and processes, thereby reducing the operating costs of the enterprise.

5. Conclusions

The unattended heating network intelligent control system realizes the automatic control of the heating station equipment, improves the heating quality, saves a lot of manpower and material resources, and reduces unnecessary waste under the premise of satisfying the user's demand. Meanwhile, managers can more clearly understand the operational data of each thermal station, making more precise management. Enterprises do not need to establish their own data centre, apply for fixed IP, and make data collection and control to each thermal station and even users only by using the user terminal with Internet access. It is also an inevitable trend of future technology development.

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