Optimization and Control Strategy Technology for User Comprehensive Energy Consumption

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Abstract. This paper studies the application of the exclusive energy controller for comprehensive energy consumption. Users' various energy consumption data such as water, gas, electricity, heat, cold are collected by controller. Various energy consumption information collection and sharing of park, community, building and other types of users can be realized by using data optimization and data fusion technology. The coupling optimization model is designed and the optimization strategy is studied, so as to realize the comprehensive state perception of energy consumption equipment and intelligent optimization control of comprehensive energy consumption.

1. Introduction
In recent years, in the face of the deepening energy and environmental crisis, it has become the common consensus of all countries in the world to consider the development of different types of energy systems from a broader macro perspective, so as to improve the comprehensive utilization efficiency of energy [1-4]. Due to the low energy density and strong intermittence, single distributed energy can’t meet the demand of energy consumption [5-7]. The distributed energy system is a complex energy system which integrates multiple energy inputs, multiple product outputs and multiple energy conversion units by considering the organic integration and integration optimization among various energy sources. Based on the conventional distributed energy technology, environmental potential energy, renewable energy, conventional energy system, new regional comprehensive energy planning, smart grid and intelligent communication control technology are coupled [8]. Through online monitoring and optimal control of users' comprehensive energy consumption, the unity of energy, environment and economic benefits can be better realized [9-12].

2. Analysis of users' energy demand
The energy demand of users mainly includes electric load, heating load, cooling load, fuel load and gas load. All kinds of energy consumption types are reflected in the industrial field, construction field and transportation field.

In terms of electric load, it can be divided into pure electric load and electric conversion load. Among them, pure power load refers to pure power consumption equipment, such as industrial machine tools in the field of industry, household appliances in the field of construction, electric vehicles in the field of transportation. Electric conversion load refers to the power consumption...
equipment that converts electric energy into heat, cold and other forms of energy for use, such as electric steam boiler in the industrial field and household air conditioning in the construction field.

Heat load can be divided into steam load and hot water load. Among them, steam load is a kind of high parameter and high-grade heat resource, which is mainly used for production process heat in industrial field and medical disinfection in construction field. The energy grade of hot water load is relatively low, and the heating load demand of main users includes the heating demand of industrial plant and building.

Cooling load can be divided into cooling load and air conditioning load. Among them, the refrigeration load refers to the demand for the purpose of creating a low-temperature environment. Its refrigeration temperature is relatively low, and it is often used in refrigeration, gas liquefaction, etc., including typical loads such as air separation in the industrial field and cold storage in the construction field. Air conditioning load refers to the cooling load to meet the demand of air conditioning and improve the comfort of office and life. Its refrigeration temperature is relatively high, including typical loads of air conditioning in industrial fields such as factory air conditioning and building air conditioning.

In terms of gas load, the terminal energy consumption on the user side is widely used, mainly including industrial gas equipment in the industrial field, domestic gas in the construction field, and natural gas vehicles in the transportation field.

3. Types and Methods of Energy Consumption Data Collection

3.1 Data acquisition mode
Through the construction of online monitoring platform, the key parameters and requirements such as the time interval and precision of terminal acquisition adapted to the platform are determined. At present, the acquisition methods are mainly as follows: one is real-time acquisition, the terminal directly collects the corresponding data items of the specified acquisition equipment, or collects all kinds of energy data, parameters and event data stored in the corresponding equipment; the other is timing automatic acquisition, which is automatically collected by the terminal The terminal automatically collects data according to the scheme set by the master station; the third is automatic supplementary reading. The terminal should have the function of automatic supplementary reading for the data not read within the specified time. When the supplementary reading fails, the event record will be generated and reported to the master station.

3.2 Data interactive communication port
Through the research on the key technologies of optimal control, the up and down communication modes and corresponding technical routes meeting the requirements of optimal control are determined. Uplink communication shall adopt optional communication mode with wireless and wired, including but not limited to Internet, wireless private network, Ethernet, power carrier, etc. Downlink communication should meet the multi scenario access needs of integrated energy service business, with access to electricity, water, gas, centralized cooling and heating and other acquisition equipment interfaces, supporting access to executive devices, etc., with wired and wireless optional communication modes, with wireless and wired mainstream optional communication modes, including RS-485, HPLC, M-BUS, Lora, CAN.

3.3 External interaction of monitoring data
It has Internet communication function, which can use internet protocol to transmit information related to comprehensive energy business. It can upgrade to adapt to future Internet protocol. It has communication fault alarm, recording and recovery function, which should be in accordance with DL / T 1867. It is required to use unified information model to interact with the master station of the system. It has security encryption function, including supporting white list identification and authentication. It supports two-way encryption transmission function and network firewall.
3.4 Parameter acquisition

Intelligent watt hour meter is used for electrical parameter acquisition. The main data acquisition includes the following aspects: the output value of watt hour meter, including phase voltage, line voltage, current, single-phase active, reactive power, total active, active power, monophasic apparent power, total apparent power, positive active power, negative active power, positive reactive power, negative reactive power and power factor. The state quantity of electric energy meter, including circuit breaker position signal, knife switch position signal, handcart position signal, valve switch signal, equipment fault signal, communication alarm signal, total accident signal, etc.

Thermal parameter acquisition uses heat meter. The main acquisition parameters include the following: first, the output value of heat meter, including real-time flow, cumulative flow, supply and return water temperature, temperature difference and cumulative working time; second, the state quantity, including valve position signal, fault signal.

Remote gas meter is used for gas parameter acquisition. The main acquisition parameters include the following: one is the output value of gas meter, including real-time, real-time flow, cumulative quantity, meter address. The other is the state quantity, including valve position signal, fault signal.

4. Optimal Control

Online monitoring and optimal control of user energy consumption mainly includes input, optimal configuration and output. Firstly, based on the analysis of users' comprehensive energy demand, the optimization of the system is proposed. Secondly, the performance of the collaborative optimization variables in the system scheme, structure, technical parameters and operation strategy is analyzed. Thirdly, based on the evaluation objective of system optimization, the mathematical modeling process is carried out. Under the premise of meeting the constraint conditions, whether it is the result of system optimization is judged. If the condition cannot be met, the optimization algorithm is used to modify the variable input, so as to cycle until the optimal solution of collaborative optimization is obtained as shown in figure 1.

According to the historical data of energy consumption including electric load, heating load, cooling load and electricity quantity, heating capacity, cooling capacity and meteorological data and the prediction results of energy demand, the load characteristics of the park are analyzed. Combined with the analysis results of the adaptability of the energy supply system configuration, the main equipment including fuel cost, initial investment cost, operation and maintenance cost, equipment characteristics and applicability of the energy supply system in the park are determined.
Figure 1. Analysis of users' comprehensive energy demand.

The model of power supply, heating, cooling equipment and energy storage equipment, as well as the conversion model of electricity, heat and cold energy are established. The optimization module of user energy supply energy system consists of optimization variables, objective function, constraints and solving algorithm. Generally speaking, the starting point of system optimization design determines the objective function in the mathematical model, which is mainly investigated from three aspects: thermodynamic performance, economic performance and environmental performance.

5. Concluding
In this paper, the application of exclusive energy controller for comprehensive energy consumption is studied. Through the energy controller, the user's various energy consumption data such as water, gas, electricity, heat, cold, sensing measurement data and working condition data are collected to realize the collection and sharing of all kinds of energy consumption information. The coupling optimization model of comprehensive energy consumption is designed to carry out the user's energy consumption. Research on the online monitoring and optimization strategy of the equipment can realize the comprehensive state perception and intelligent optimization control of energy consumption.

References
[1] Mahmoodi, M., Shamsi, P., & Fahimi, B. (2015). Economic dispatch of a hybrid microgrid with distributed energy storage. IEEE Transactions on Smart Grid, 6(6), 2607-2614.
[2] Li, M., Mu, H., Li, N., & Ma, B. (2016). Optimal design and operation strategy for integrated evaluation of cchp (combined cooling heating and power) system. Energy, 99(mar.15), 202-220.
[3] Guo, F., Wen, C., Mao, J., Chen, J., & Song, Y. D. (2015). Distributed cooperative secondary control for voltage unbalance compensation in an islanded microgrid. Industrial Informatics IEEE Transactions on, 11(5), 1078-1088.

[4] Guotai, Z., Hao, L., Baoguo, Z., et al. (2018). Comprehensive optimization of electrical thermal energy storage equipments for integrated energy system near user side based on energy supply and demand balance. Power System Protection and Control, 46(16), 8-18.

[5] Ting, Y., Liyuan, Z., Chengshan, W. (2019). Review on application of artificial intelligence in power system and integrated energy system. Automation of Electric Power Systems, 43(1), 2-14.

[6] Haozhong, C., Xiao, H., & Li, W. (2019). Review on research of regional integrated energy system planning. Automation of Electric Power Systems, 43(7), 2-13.

[7] Qirui, Q., Gengfeng, L., & Yuqing, P. (2018). Research on user load classification based on synthetic index of electricity consumption behavior. Smart Power, 46(10), 26-31.

[8] Ke, P., Cong, Z., Bingyin, X., et al. (2017). Status and prospect of pilot projects of integrated energy system with multi-energy collaboration. Electric Power Automation Equipment, 37(6), 3-10.

[9] Yang, L., Tianli, S., & Zijian, W. (2018). Research on key issues of integrated energy services based on user data deep-mining. Power Demand Side Management, 20(3), 1-5.

[10] Ming, Z., Daoxin, L., & Na, L. (2013). Key economic issues in integrated energy system. East China Electric Power, 41(7), 1403-1408.

[11] Zhu, F., Yang, Z., Lin, F., & Xin, Y. (2020). Decentralized cooperative control of multiple energy storage systems in urban railway based on multi-agent deep reinforcement learning. IEEE Transactions on Power Electronics, PP(99), 1-1.

[12] Heckel, J. P., & Becker, C. (2020). Investigation of the Voltage Stability in the Integrated Energy System of Northern Germany. NEIS 2020 Conference on Sustainable Energy Supply and Energy Storage Systems.